Conversations on Geology

Granville Penn

ISLE OF ANGLESEA

Section of Alum Bay Isle of Wight

ISLE OF WIGHT

Wm Corrigan's 7/2 – 7d

CONVERSATIONS ON GEOLOGY;

1052

COMPRISING

A Familiar Explanation

OF THE

HUTTONIAN AND WERNERIAN SYSTEMS;

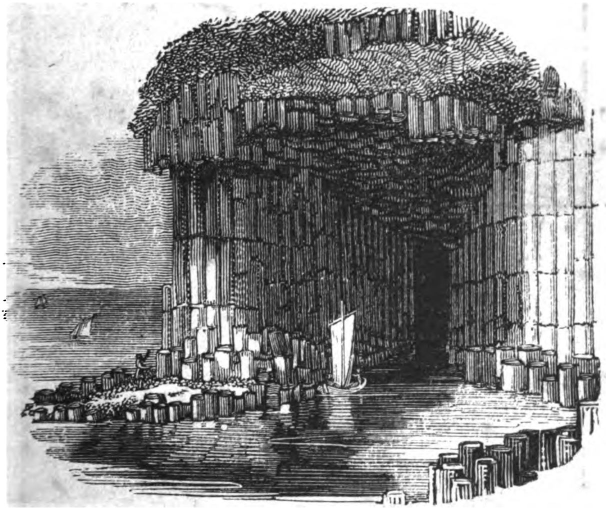
THE MOSAIC GEOLOGY,

AS EXPLAINED BY

MR. GRANVILLE PENN;

AND THE

LATE DISCOVERIES OF PROFESSOR BUCKLAND, HUMBOLDT, DR. MACCULLOCH, AND OTHERS.



LONDON:
PRINTED FOR SAMUEL MAUNDER,
NEWGATE STREET.

1828.

PREFACE.

By those who regard a knowledge of the earth's structure, so far as it lies open to human observation, as a science worthy of the attention of youth, no apology will be thought necessary for the attempt which has been here made to simplify and render its study inviting, by introducing it in the popular form of "CONVERSATIONS."

The primary objects of Geological inquiry are, to ascertain, by patient investigation, of what the great masses consist which compose the crust of the globe, in what manner they are arranged, and what is their probable origin. Until the sciences of Chemistry and Mineralogy had made considerable advances towards that state of perfection in which we now find them, Geology was scarcely understood at all; and, accordingly, the wildest theorists had unbounded scope for the erection of fanciful hypotheses. But, as we have

endeavoured, in the "Conversations," to describe the various Theories of the Earth and Systems of Geology which have, from time to time, prevailed, and have brought forward facts and reasonings either in support or contradiction of them, there is no necessity for us in this place to point them out, or to allude to the peculiarities by which they are contradistinguished. A more important consideration presents itself. We are enabled to

"Look through Nature up to Nature's God."

We find that, however hidden from human discernment may be the original formation and organization of the earth, its arrangement is evidently calculated to supply the wants and gratify the desires of man; and it exhibits, though less obviously perhaps than the animal and vegetable world, the same paternal care of an all-directing Providence,

"Whose wond'rous power
Presided o'er Creation's natal hour."

On this subject we cannot do better than make a few extracts from the observations of Professor Buckland, who, in adducing proofs of the earth's structure being made subservient to final causes, and those causes being manifestly intended to operate in favour of the beings which God has created, thus argues:—

"A great majority of the strata having been formed under water, and from materials evidently in such a state as to subject their arrangement to the operation of the laws of gravitation, had no disturbing forces interposed, they must have formed layers almost regularly horizontal, and therefore investing in concentric coates the nucleus of the earth. But the actual position of these beds is generally more or less inclined to the horizontal plane, though often under an angle almost imperceptible. By this arrangement, many strata, affording numerous varieties of mineral productions, are made to emerge in succession on the surface of the earth; whereas the inferior must have been buried for ever beneath the highest, had their position been strictly horizontal; and, in such case, we should have wanted that variety of useful minerals almost indispensable to the existence of man in a state of civil society, which this succession of different strata now presents to us.

"In the whole machinery also of springs and rivers, and the apparatus that is kept in action for their duration, through the instrumentality of a system of curiously constructed hills and valleys, receiving their supply *occasionally* from the rains of heaven, and treasuring up in their everlasting storehouses to be dispensed *perpetually* by thousands of never-failing fountains, we see a provision not less striking or less important. So also

in the adjustment of the relative quantities of sea and land in such due proportions as to supply the earth by constant evaporation, without diminishing the waters of the ocean; and in the appointment of the atmosphere to be the vehicle of this wonderful and unceasing circulation; in thus separating these waters from their native salt (which, though of the highest utility to preserve the purity of the sea, renders them unfit for the support of terrestrial animals or vegetables), and transmitting them in genial showers to scatter fertility over the earth, and maintain the never-failing reservoirs of those springs and rivers by which it is again returned to mix with its parent ocean: in all these we find such undeniable proofs of a nicely balanced adaptation of means to ends, of wise foresight and benevolent intention and infinite power, that he must be blind indeed who refuses to recognize in them proofs of the most exalted attributes of the Creator.

"Another valuable contrivance in the structure of the globe is, that nearly all its materials are such as to afford, by their decomposition, a soil fit for the support of vegetable life; and that they are calculated to undergo, and have undergone, a superficial decomposition. Here is an instance of relation between the vegetable and mineral kingdoms, and of the adaptation of one to the other, which always implies design in the

surest manner: for had not the surface of the earth been thus prepared for their reception, where would have been the use of all that admirable system of organization bestowed upon vegetables? And it is no small proof of design in the arrangement of the materials that compose the surface of our earth, that whereas the primitive and granitic rocks are least calculated to afford a fertile soil, they are for the most part made to constitute the mountain districts of the world, which, from their elevation and irregularities, would otherwise be but ill adapted for human habitation; whilst the lower and more temperate regions are usually composed of derivative or secondary strata, in which the compound nature of their ingredients qualifies them to be of the greatest utility to mankind by their subserviency to the purposes of luxuriant vegetation.

"Thus Geology contributes proofs to Natural Theology, strictly in harmony with those derived from other branches of natural history; and if it be allowed, on the one hand, that these proofs are in this science less numerous and obvious, it may be contended, on the other, that they are calculated to lead us a step farther in our inferences. The evidences afforded by the sister sciences exhibit, indeed, the most admirable proofs of design and intelligence originally exerted at the Creation: but many who admit these proofs still doubt the con-

tinued superintendence of that intelligence, maintaining that the system of the universe is carried on by the force of the laws originally impressed on matter, without the necessity of fresh interference or continued supervision on the part of the Creator. Such an opinion is, indeed, founded only on a verbal fallacy; for 'laws impressed on matter,' is an expression which can only denote the continued exertion of the will of the lawgiver, the prime agent, the first mover: still, however, the opinion has been entertained, and perhaps it nowhere meets with a more direct and palpable refutation than is afforded by the subserviency of the present structure of the earth's surface to final causes; for that structure is evidently the result of many and violent convulsions subsequent to its original formation. When, therefore, we perceive that the secondary causes producing these convulsions have operated at successive periods, not blindly and at random, but with a direction to beneficial ends, we see at once the proofs of an overruling intelligenee continuing to superintend, direct, modify, and control the operations of the agents, which he originally ordained.

"The consideration, also, of the evidences afforded by Geological phœnomena may enable us to lay more securely the very foundations of Natural Theology, inasmuch as they clearly point out to us a period antecedent to the habitable

state of the earth, and consequently antecedent to the existence of its inhabitants. When our minds become thus familiarized with the idea of a beginning and first creation of the beings we see around us, the proofs of design, which the structure of those beings affords, carry with them a more forcible conviction of an intelligent Creator, and the hypothesis of an eternal succession of causes is thus at once removed. We argue thus — it is demonstrable from Geology that there was a period when no organic beings had existence: these organic beings must therefore have had a beginning subsequently to this period; and where is that beginning to be found, but in the will and *fiat* of an intelligent and all-wise Creator?"

May we not, then, well exclaim in the words of a modern poet,

> "There is a voiceless eloquence on earth,
> Telling of Him who gave her wonders birth;
> And long may I remain the adoring child
> Of Nature's majesty, sublime or wild;
> Hill, flood, and forest, mountain, rock, and sea,
> All take their terrors and their charms from Thee,
> From Thee, whose hidden but supreme control
> Moves through the world, a universal soul!" *

---

* Vide "*The Omnipresence of the Deity,*" a Poem. By Robert Montgomery.

CONTENTS

OF THE

CONVERSATIONS ON GEOLOGY.

CONVERSATION FIRST.

Theories of the Earth.

CONVERSATION SECOND.

Geological Cabinet.

CONVERSATION THIRD.

Systems of Geology.

CONVERSATION FOURTH.

First Principles of the Wernerian System.

CONVERSATION FIFTH.

Effects of Expansion arising from a Central Fire.

CONVERSATION SIXTH.

Formation of Ravines, Valleys, and River-Courses.

CONVERSATION SEVENTH.

Origin of Glaciers and Deserts.

CONVERSATION EIGHTH.

Origin of Islands from Coral and Volcanos.

tinued superintendence of that intelligence, maintaining that the system of the universe is carried on by the force of the laws originally impressed on matter, without the necessity of fresh interference or continued supervision on the part of the Creator. Such an opinion is, indeed, founded only on a verbal fallacy; for 'laws impressed on matter,' is an expression which can only denote the continued exertion of the will of the lawgiver, the prime agent, the first mover: still, however, the opinion has been entertained, and perhaps it nowhere meets with a more direct and palpable refutation than is afforded by the subserviency of the present structure of the earth's surface to final causes; for that structure is evidently the result of many and violent convulsions subsequent to its original formation. When, therefore, we perceive that the secondary causes producing these convulsions have operated at successive periods, not blindly and at random, but with a direction to beneficial ends, we see at once the proofs of an overruling intelligence continuing to superintend, direct, modify, and control the operations of the agents, which he originally ordained.

"The consideration, also, of the evidences afforded by Geological phœnomena may enable us to lay more securely the very foundations of Natural Theology, inasmuch as they clearly point out to us a period antecedent to the habitable

state of the earth, and consequently antecedent to the existence of its inhabitants. When our minds become thus familiarized with the idea of a beginning and first creation of the beings we see around us, the proofs of design, which the structure of those beings affords, carry with them a more forcible conviction of an intelligent Creator, and the hypothesis of an eternal succession of causes is thus at once removed. We argue thus — it is demonstrable from Geology that there was a period when no organic beings had existence: these organic beings must therefore have had a beginning subsequently to this period; and where is that beginning to be found, but in the will and *fiat* of an intelligent and all-wise Creator?"

May we not, then, well exclaim in the words of a modern poet,

> "There is a voiceless eloquence on earth,
> Telling of Him who gave her wonders birth;
> And long may I remain the adoring child
> Of Nature's majesty, sublime or wild;
> Hill, flood, and forest, mountain, rock, and sea,
> All take their terrors and their charms from Thee,
> From Thee, whose hidden but supreme control
> Moves through the world, a universal soul!" *

---

* Vide "*The Omnipresence of the Deity,*" a Poem. By Robert Montgomery.

CONTENTS

OF THE

CONVERSATIONS ON GEOLOGY.

CONVERSATION FIRST.

Theories of the Earth.

CONVERSATION SECOND.

Geological Cabinet.

CONVERSATION THIRD.

Systems of Geology.

CONVERSATION FOURTH.

First Principles of the Wernerian System.

CONVERSATION FIFTH.

Effects of Expansion arising from a Central Fire.

CONVERSATION SIXTH.

Formation of Ravines, Valleys, and River-Courses.

CONVERSATION SEVENTH.

Origin of Glaciers and Deserts.

CONVERSATION EIGHTH.

Origin of Islands from Coral and Volcanos.

CONVERSATION NINTH.

Origin of Valleys, Plains, Marshes, Bogs, and Lakes.

CONVERSATION TENTH.

Order of Rocks, with the Origin of Coal, and Diffusion of Gravel and Sand in the Sea.

CONVERSATION ELEVENTH.

Consolidation and Hardening of Rocks.

CONVERSATION TWELFTH.

Mineral Rocks.

CONVERSATION THIRTEENTH.

Mosaic Geology, as explained by Mr. Penn.

CONVERSATION FOURTEENTH.

Bones and Shells in Rocks and Caverns, and in the Soil.

in the adjustment of the relative quantities of sea and land in such due proportions as to supply the earth by constant evaporation, without diminishing the waters of the ocean; and in the appointment of the atmosphere to be the vehicle of this wonderful and unceasing circulation; in thus separating these waters from their native salt (which, though of the highest utility to preserve the purity of the sea, renders them unfit for the support of terrestrial animals or vegetables), and transmitting them in genial showers to scatter fertility over the earth, and maintain the never-failing reservoirs of those springs and rivers by which it is again returned to mix with its parent ocean: in all these we find such undeniable proofs of a nicely balanced adaptation of means to ends, of wise foresight and benevolent intention and infinite power, that he must be blind indeed who refuses to recognize in them proofs of the most exalted attributes of the Creator.

"Another valuable contrivance in the structure of the globe is, that nearly all its materials are such as to afford, by their decomposition, a soil fit for the support of vegetable life; and that they are calculated to undergo, and have undergone, a superficial decomposition. Here is an instance of relation between the vegetable and mineral kingdoms, and of the adaptation of one to the other, which always implies design in the

surest manner: for had not the surface of the earth been thus prepared for their reception, where would have been the use of all that admirable system of organization bestowed upon vegetables? And it is no small proof of design in the arrangement of the materials that compose the surface of our earth, that whereas the primitive and granitic rocks are least calculated to afford a fertile soil, they are for the most part made to constitute the mountain districts of the world, which, from their elevation and irregularities, would otherwise be but ill adapted for human habitation; whilst the lower and more temperate regions are usually composed of derivative or secondary strata, in which the compound nature of their ingredients qualifies them to be of the greatest utility to mankind by their subserviency to the purposes of luxuriant vegetation.

"Thus Geology contributes proofs to Natural Theology, strictly in harmony with those derived from other branches of natural history; and if it be allowed, on the one hand, that these proofs are in this science less numerous and obvious, it may be contended, on the other, that they are calculated to lead us a step farther in our inferences. The evidences afforded by the sister sciences exhibit, indeed, the most admirable proofs of design and intelligence originally exerted at the Creation: but many who admit these proofs still doubt the con-

tinued superintendence of that intelligence, maintaining that the system of the universe is carried on by the force of the laws originally impressed on matter, without the necessity of fresh interference or continued supervision on the part of the Creator. Such an opinion is, indeed, founded only on a verbal fallacy; for 'laws impressed on matter,' is an expression which can only denote the continued exertion of the will of the lawgiver, the prime agent, the first mover: still, however, the opinion has been entertained, and perhaps it nowhere meets with a more direct and palpable refutation than is afforded by the subserviency of the present structure of the earth's surface to final causes; for that structure is evidently the result of many and violent convulsions subsequent to its original formation. When, therefore, we perceive that the secondary causes producing these convulsions have operated at successive periods, not blindly and at random, but with a direction to beneficial ends, we see at once the proofs of an overruling intelligence continuing to superintend, direct, modify, and control the operations of the agents, which he originally ordained.

"The consideration, also, of the evidences afforded by Geological phœnomena may enable us to lay more securely the very foundations of Natural Theology, inasmuch as they clearly point out to us a period antecedent to the habitable

state of the earth, and consequently antecedent to the existence of its inhabitants. When our minds become thus familiarized with the idea of a beginning and first creation of the beings we see around us, the proofs of design, which the structure of those beings affords, carry with them a more forcible conviction of an intelligent Creator, and the hypothesis of an eternal succession of causes is thus at once removed. We argue thus — it is demonstrable from Geology that there was a period when no organic beings had existence: these organic beings must therefore have had a beginning subsequently to this period; and where is that beginning to be found, but in the will and *fiat* of an intelligent and all-wise Creator?"

May we not, then, well exclaim in the words of a modern poet,

"There is a voiceless eloquence on earth,
Telling of Him who gave her wonders birth;
And long may I remain the adoring child
Of Nature's majesty, sublime or wild;
Hill, flood, and forest, mountain, rock, and sea,
All take their terrors and their charms from Thee,
From Thee, whose hidden but supreme control
Moves through the world, a universal soul!" *

* Vide "*The Omnipresence of the Deity*," a Poem. By Robert Montgomery.

CONTENTS

OF THE

CONVERSATIONS ON GEOLOGY.

CONVERSATION FIRST.

Theories of the Earth.

CONVERSATION SECOND.

Geological Cabinet.

CONVERSATION THIRD.

Systems of Geology.

CONVERSATION FOURTH.

First Principles of the Wernerian System.

CONVERSATION FIFTH.

Effects of Expansion arising from a Central Fire.

CONVERSATION SIXTH.

Formation of Ravines, Valleys, and River-Courses.

CONVERSATION SEVENTH.

Origin of Glaciers and Deserts.

CONVERSATION EIGHTH.

Origin of Islands from Coral and Volcanos.

CONVERSATION NINTH.

Origin of Valleys, Plains, Marshes, Bogs, and Lakes.

CONVERSATION TENTH.

Order of Rocks, with the Origin of Coal, and Diffusion of Gravel and Sand in the Sea.

CONVERSATION ELEVENTH.

Consolidation and Hardening of Rocks.

CONVERSATION TWELFTH.

Mineral Rocks.

CONVERSATION THIRTEENTH.

Mosaic Geology, as explained by Mr. Penn.

CONVERSATION FOURTEENTH.

Bones and Shells in Rocks and Caverns, and in the Soil.

CONVERSATION SECOND.

Geological Cabinet.

CONVERSATION THIRD.

Systems of Geology.

CONVERSATION FOURTH.

First Principles of the Wernerian System.

CONVERSATION FIFTH.

Effects of Expansion arising from a Central Fire.

CONVERSATION SIXTH.

Formation of Ravines, Valleys, and River-Courses.

CONVERSATION SEVENTH.

Origin of Glaciers and Deserts.

CONVERSATION EIGHTH.

Origin of Islands from Coral and Volcanos.

in the adjustment of the relative quantities of sea and land in such due proportions as to supply the earth by constant evaporation, without diminishing the waters of the ocean; and in the appointment of the atmosphere to be the vehicle of this wonderful and unceasing circulation; in thus separating these waters from their native salt (which, though of the highest utility to preserve the purity of the sea, renders them unfit for the support of terrestrial animals or vegetables), and transmitting them in genial showers to scatter fertility over the earth, and maintain the never-failing reservoirs of those springs and rivers by which it is again returned to mix with its parent ocean: in all these we find such undeniable proofs of a nicely balanced adaptation of means to ends, of wise foresight and benevolent intention and infinite power, that he must be blind indeed who refuses to recognize in them proofs of the most exalted attributes of the Creator.

" Another valuable contrivance in the structure of the globe is, that nearly all its materials are such as to afford, by their decomposition, a soil fit for the support of vegetable life; and that they are calculated to undergo, and have undergone, a superficial decomposition. Here is an instance of relation between the vegetable and mineral kingdoms, and of the adaptation of one to the other, which always implies design in the

surest manner: for had not the surface of the earth been thus prepared for their reception, where would have been the use of all that admirable system of organization bestowed upon vegetables? And it is no small proof of design in the arrangement of the materials that compose the surface of our earth, that whereas the primitive and granitic rocks are least calculated to afford a fertile soil, they are for the most part made to constitute the mountain districts of the world, which, from their elevation and irregularities, would otherwise be but ill adapted for human habitation; whilst the lower and more temperate regions are usually composed of derivative or secondary strata, in which the compound nature of their ingredients qualifies them to be of the greatest utility to mankind by their subserviency to the purposes of luxuriant vegetation.

"Thus Geology contributes proofs to Natural Theology, strictly in harmony with those derived from other branches of natural history; and if it be allowed, on the one hand, that these proofs are in this science less numerous and obvious, it may be contended, on the other, that they are calculated to lead us a step farther in our inferences. The evidences afforded by the sister sciences exhibit, indeed, the most admirable proofs of design and intelligence originally exerted at the Creation: but many who admit these proofs still doubt the con-

tinued superintendence of that intelligence, maintaining that the system of the universe is carried on by the force of the laws originally impressed on matter, without the necessity of fresh interference or continued supervision on the part of the Creator. Such an opinion is, indeed, founded only on a verbal fallacy; for 'laws impressed on matter,' is an expression which can only denote the continued exertion of the will of the lawgiver, the prime agent, the first mover: still, however, the opinion has been entertained, and perhaps it nowhere meets with a more direct and palpable refutation than is afforded by the subserviency of the present structure of the earth's surface to final causes; for that structure is evidently the result of many and violent convulsions subsequent to its original formation. When, therefore, we perceive that the secondary causes producing these convulsions have operated at successive periods, not blindly and at random, but with a direction to beneficial ends, we see at once the proofs of an overruling intelligence continuing to superintend, direct, modify, and control the operations of the agents, which he originally ordained.

"The consideration, also, of the evidences afforded by Geological phœnomena may enable us to lay more securely the very foundations of Natural Theology, inasmuch as they clearly point out to us a period antecedent to the habitable

state of the earth, and consequently antecedent to the existence of its inhabitants. When our minds become thus familiarized with the idea of a beginning and first creation of the beings we see around us, the proofs of design, which the structure of those beings affords, carry with them a more forcible conviction of an intelligent Creator, and the hypothesis of an eternal succession of causes is thus at once removed. We argue thus — it is demonstrable from Geology that there was a period when no organic beings had existence: these organic beings must therefore have had a beginning subsequently to this period; and where is that beginning to be found, but in the will and *fiat* of an intelligent and all-wise Creator?"

May we not, then, well exclaim in the words of a modern poet,

"There is a voiceless eloquence on earth,
Telling of Him who gave her wonders birth;
And long may I remain the adoring child
Of Nature's majesty, sublime or wild;
Hill, flood, and forest, mountain, rock, and sea,
All take their terrors and their charms from Thee,
From Thee, whose hidden but supreme control
Moves through the world, a universal soul!" *

---

* Vide "*The Omnipresence of the Deity*," a Poem. By Robert Montgomery.

CONTENTS

OF THE

CONVERSATIONS ON GEOLOGY.

CONVERSATION FIRST.

Theories of the Earth.

CONVERSATION SECOND.

Geological Cabinet.

CONVERSATION THIRD.

Systems of Geology.

CONVERSATION FOURTH.

First Principles of the Wernerian System.

CONVERSATION FIFTH.

Effects of Expansion arising from a Central Fire.

CONVERSATION SIXTH.

Formation of Ravines, Valleys, and River-Courses.

CONVERSATION SEVENTH.

Origin of Glaciers and Deserts.

CONVERSATION EIGHTH.

Origin of Islands from Coral and Volcanos.

CONVERSATION NINTH.

Origin of Valleys, Plains, Marshes, Bogs, and Lakes.

CONVERSATION TENTH.

Order of Rocks, with the Origin of Coal, and Diffusion of Gravel and Sand in the Sea.

CONVERSATION ELEVENTH.

Consolidation and Hardening of Rocks.

CONVERSATION TWELFTH.

Mineral Rocks.

CONVERSATION THIRTEENTH.

Mosaic Geology, as explained by Mr. Penn.

CONVERSATION FOURTEENTH.

Bones and Shells in Rocks and Caverns, and in the Soil.

CONVERSATION FIFTEENTH.

The Great Rock Basins of London, Paris, and the Isle of Wight, with the Extinct Animals of a Former World.

LIST OF ENGRAVINGS.

ERRATA.

[The following literal errors have been discovered since the volume was printed, which, as they occurred during the Author's absence, will, it is hoped, be excused.]

Page 9, line 7, *for* calml, *read* calmly.
35, —— 6 from the bottom, *for* angite, *read* augite.
48, —— 12 *for* disintegnated, *read* disintegrated.
166, —— 8 *for* Dolomien, *read* Dolomieu.
202, —— 4 from the bottom, *for* De Lac, *read* De Luc.

Conversations on Geology.

CONVERSATION FIRST.

THEORIES OF THE EARTH.

EDWARD.

SEA-SHELLS, did you say, mother, in the heart of solid rocks, and far inland? There must surely be some mistake in this; at least, it appears to me to be incredible.

MRS. R.

Incredible as you suppose it to be, my dear boy, you may see it with your own eyes in the marble of this chimney-piece, which, you may perceive, is throughout studded with shells, as if they were fresh from the sea. They even retain, as you perceive, their original *nacre,* as the French call the peculiar lustre of mother-of-pearl.

CHRISTINA.

Ah, so they do; but I dare say it is only a good imitation of shells made on the marble. There is a very pretty one on the lid of my work-box, which is certainly artificial, and those in the marble may have been done in the same way.

MRS. R.

But, my dear, there is no *nacre* on the shell in your work-box, and it is evident, indeed, that it is wholly made of pieces of stained wood, ingeniously put together; but the shells in the marble are real shells, as you may see, differing in nothing from those we find on the seashore.

EDWARD.

Then how could they come into the marble? It must have been soft, like paste, or have been precipitated or deposited, as we say in chemistry, over the shells; for they are distributed, as I perceive, through its substance.

MRS. R.

Yes; and, if you were to break the marble into a thousand fragments, you would find a shell in almost every one of them.

CHRISTINA.

Is there any history of these curious shells, mother? I should like, above all things, to read it. I suppose it must be something like the stories I have seen of living toads found in the heart of growing trees.

MRS. R.

The history of the shells, my dear, and many other things no less wonderful, is contained in the science called GEOLOGY, which treats of the first appearance of rocks, mountains, valleys, lakes, and rivers; and the changes they have undergone, from the Creation and the Deluge, till the present time.

CHRISTINA.

I always thought that the lakes, mountains, and valleys, had been created from the first by God, and that no farther history could be given of them.

MRS. R.

True, my dear; but yet we may, without presumption, inquire into what actually took place at the creation; and, by examining stones and rocks as we now find them, endeavour to trace what changes they have undergone in the course of ages.

EDWARD.

I should like, very much, to know something of those curious subjects; but I fear I could not understand them. Is there any easy book on Geology, like the delightful "Conversations on Chemistry," which I could read without being puzzled?

MRS. R.

There is no book of this kind that I know of, as Geology is still a new science, and has not yet produced any popular writer; but suppose we try to do without a book, since you are so anxious to learn it. I have had some opportunities of acquiring a knowledge of the principal facts and discussions of Geology, and I shall be delighted to explain them to you.

CHRISTINA.

Could I understand them also, mother, I should like to learn Geology, if it is as interesting as chemistry?

MRS. R.

It is much more so, I can assure you; and what you have learned of chemistry from the "Conversations," and from the experiments which Edward and you have lately been making, will be of great

advantage to you in learning Geology, as it cannot be well understood without a knowledge of chemistry.

EDWARD.

And when will you give us our first lesson, mother? I am impatient to know the history of the sea-shells in the marble.

MRS. R.

Impatience, my dear, I may tell you, will never make you a good Geologist; and we must go through a great many facts and conjectures, before we come to the history of the shells, besides some pretty romances, which are called Theories of the earth, and tell us how the world was made.

CHRISTINA.

Then I am sure I shall like it, for I delight in romances; and whenever I hear the word, I think of the Happy Valley in "Rasselas," Robinson Crusoe's Island, or the Enchanted Gardens of Armida; but I always thought there were no romances in philosophy.

MRS. R.

You mean, perhaps, that there should be none; but philosophers, if they have much imagination,

are apt to let it loose as well as other people, and in such cases are sometimes led to mistake a fancy for a fact. Geologists, in particular, have very frequently amused themselves in this way, and it is not a little amusing to follow them in their fancies and their waking dreams. Geology, indeed, in this view, may be called a romantic science.

EDWARD.

A romantic science, mother? That is certainly a very unusual expression.

MRS. R.

That is of little consequence, if it be correct; and I think I can show it to be so, even independently of the fanciful systems which I have just hinted at. Do you not say, Christina, that botany is a beautiful science?

CHRISTINA.

Yes; I think it is, indeed; for it invites us to the fields in the beautiful months of spring and summer, and makes us admire the beauty of the budding trees, the springing grass, and the opening blossoms: it enhances the pleasure of every walk, and sometimes, I have fancied, makes the

sunshine itself look brighter when it falls upon the flower-garden.

MRS. R.

And have I not heard you, Edward, calling astronomy a sublime science?

EDWARD.

It deserves, indeed, to be called so, I think; for it raises our thoughts above the earth and its little scene of change and bustle, and leads the mind to contemplate the starry universe and the infinity of space, which God has peopled with suns and worlds.

MRS. R.

Then, if you call botany beautiful, and astronomy sublime, for the reasons you have just given, I, in the same way, call Geology romantic, because it not only leads us to travel among the wildest scenery of nature, but carries the imagination back to the birth and infancy of our little planet, and follows its history of deluges and hurricanes and earthquakes, which have left us numerous traces of their devastations. Would you not think it romantic to travel, as must be done by the geological inquirer, among mountains and valleys, where the tempests have bared and

shattered the hardest rocks, and where alternate rains and frosts are crumbling the solid materials of mountains, while the springs and rivers wash away the fragments, to deposit them again in the various stages of their course? And would you not think it romantic to dream about the young world emerging from darkness, and rejoicing in the first dawn of created light? To think of the building of mountains, the hollowing out of valleys, and the gathering together of the great waters of the ocean? And will it not be romantic to discover the traces of the ancient world before the time of Noah, in every hill and valley which you examine?

EDWARD.

This will, indeed, be romantic and interesting, though I am not sure I shall understand it so well as astronomy.

MRS. R.

On the contrary, I think Geology is, perhaps, better fitted for our limited comprehensions than astronomy; for it is more within our reach to examine the structure and formation of mountains, than that of the sun or of the stars; and it is easier to bring the mind to rest on the compara-

tive littleness of the earth at its creation, than to let our thoughts travel abroad through the boundless fields of infinite space. When we descend to the earth, we feel ourselves more at home; we are not so overpowered by sublimity as in the contemplation of astronomy; we can think more calml and reason more at ease; and we can trace the finger of God more visibly, perhaps, because more nearly.

EDWARD.

You may permit me to say, however, that, in studying astronomy, we can see the continual changes caused by the revolution of the planets and their satellites; but I cannot imagine that you can see such changes in mountains, rocks, and valleys.

MRS. R.

No, my dear; but we can infer from their appearances, by examining them carefully, that they have been subject sometimes to chemical and sometimes to mechanical changes, either lately or in very early times; and, as we proceed with our proposed lessons, we shall have many examples to convince you of this.

EDWARD.

You mentioned, a little time ago, that Geology is a new science: now, I think that is strange, for philosophers must always have observed the appearances of mountains and valleys, and it is their business to explain, or at least endeavour to explain, whatever they observe.

MRS. R.

Yes; but philosophers, till within the last few years, were more anxious to go upon what they fancied, than upon what they saw; and to contrive systems and theories, than to examine facts; and the consequence was, that there were many *Theories of the Earth*, as they were called, but these cannot with much propriety be looked upon as Geology:—that, like other sciences, must be founded on fact.

EDWARD.

But there must have been some grounds, at least, for these theories of the earth—something plausible or interesting; otherwise nobody would have attended to them.

MRS. R.

That I shall leave you to determine, after hearing the nature of a few of them. Burnet, the first of the theorists worthy of notice, says that, before the Deluge of Noah, the earth consisted of a light crust or shell, of uniform thickness, with the waters of the sea under it; that there were no mountains, no valleys, but one smooth unvarying surface over the whole earth; and that this crust, being broken up at the Deluge, formed the rocks and mountains as they at present exist.

EDWARD.

I think this is all very plausible, for it is said in Genesis, "that the fountains of the great deep were broken up!"

MRS. R.

But it is no where said that before the Deluge there were no rocks, mountains, nor valleys.

CHRISTINA.

If it was so, the earth must have looked a sad melancholy flat; Salisbury Plain is quite enough of such a landscape. Burnet, I should think, would have made a very sorry poet.

MRS. R.

On the contrary, his book is highly poetical, and is now read on that account alone. You may remark, that there could have been no rivers in this smooth mountainless world, for water cannot run unless there be a declivity.* Burnet, indeed, saw no use for water before the deluge, for there was no rain, he says, in these antediluvian times. I dare say, Edward, you will be more pleased with Woodward, whose theory undertakes to explain how shells became imbedded in marble and other rocks.

EDWARD.

That is precisely what I long so much to understand.

MRS. R.

Woodward says, the deluge was caused by all the solid parts of the earth dissolving and forming a paste, among which the sea-shells were mingled, by the agitation which then took place.

EDWARD.

But how were the rocks dissolved? I should

* See Conversations on Natural Philosophy, Conv. XI.

like to know what it is that could destroy their cohesion.

MRS. R.

Woodward says that the powers of cohesion among minerals was suspended, so that their parts no longer adhered firmly together; but he has no other authority for this than his own fanciful conjectures: so, Edward, you must lay your account for a little disappointment; and, as you are fond of astronomy, I shall console you with an account of the theories of the earth derived, or partly derived, from it.

EDWARD.

I cannot perceive what connexion there can be between astronomy and the origin of rocks and mountains.

MRS. R.

Whiston, for example, supposed that the deluge was caused by the tail of a comet; Descartes and Leibnitz conceived that the earth was an old sun with its fire extinguished; and the celebrated naturalist, Buffon, fancied that a comet struck off a corner from our present sun, and this, being melted by heat, formed the earth, which is now gradually cooling.

EDWARD.

I should like, very much, to know something of those curious subjects; but I fear I could not understand them. Is there any easy book on Geology, like the delightful "Conversations on Chemistry," which I could read without being puzzled?

MRS. R.

There is no book of this kind that I know of, as Geology is still a new science, and has not yet produced any popular writer; but suppose we try to do without a book, since you are so anxious to learn it. I have had some opportunities of acquiring a knowledge of the principal facts and discussions of Geology, and I shall be delighted to explain them to you.

CHRISTINA.

Could I understand them also, mother, I should like to learn Geology, if it is as interesting as chemistry?

MRS. R.

It is much more so, I can assure you; and what you have learned of chemistry from the "Conversations," and from the experiments which Edward and you have lately been making, will be of great

advantage to you in learning Geology, as it cannot be well understood without a knowledge of chemistry.

EDWARD.

And when will you give us our first lesson, mother? I am impatient to know the history of the sea-shells in the marble.

MRS. R.

Impatience, my dear, I may tell you, will never make you a good Geologist; and we must go through a great many facts and conjectures, before we come to the history of the shells, besides some pretty romances, which are called Theories of the earth, and tell us how the world was made.

CHRISTINA.

Then I am sure I shall like it, for I delight in romances; and whenever I hear the word, I think of the Happy Valley in "Rasselas," Robinson Crusoe's Island, or the Enchanted Gardens of Armida; but I always thought there were no romances in philosophy.

MRS. R.

You mean, perhaps, that there should be none; but philosophers, if they have much imagination,

are apt to let it loose as well as other people, and in such cases are sometimes led to mistake a fancy for a fact. Geologists, in particular, have very frequently amused themselves in this way, and it is not a little amusing to follow them in their fancies and their waking dreams. Geology, indeed, in this view, may be called a romantic science.

EDWARD.

A romantic science, mother? That is certainly a very unusual expression.

MRS. R.

That is of little consequence, if it be correct; and I think I can show it to be so, even independently of the fanciful systems which I have just hinted at. Do you not say, Christina, that botany is a beautiful science?

CHRISTINA.

Yes; I think it is, indeed; for it invites us to the fields in the beautiful months of spring and summer, and makes us admire the beauty of the budding trees, the springing grass, and the opening blossoms: it enhances the pleasure of every walk, and sometimes, I have fancied, makes the

sunshine itself look brighter when it falls upon the flower-garden.

MRS. R.

And have I not heard you, Edward, calling astronomy a sublime science?

EDWARD.

It deserves, indeed, to be called so, I think; for it raises our thoughts above the earth and its little scene of change and bustle, and leads the mind to contemplate the starry universe and the infinity of space, which God has peopled with suns and worlds.

MRS. R.

Then, if you call botany beautiful, and astronomy sublime, for the reasons you have just given, I, in the same way, call Geology romantic, because it not only leads us to travel among the wildest scenery of nature, but carries the imagination back to the birth and infancy of our little planet, and follows its history of deluges and hurricanes and earthquakes, which have left us numerous traces of their devastations. Would you not think it romantic to travel, as must be done by the geological inquirer, among mountains and valleys, where the tempests have bared and

shattered the hardest rocks, and where alternate rains and frosts are crumbling the solid materials of mountains, while the springs and rivers wash away the fragments, to deposit them again in the various stages of their course? And would you not think it romantic to dream about the young world emerging from darkness, and rejoicing in the first dawn of created light? To think of the building of mountains, the hollowing out of valleys, and the gathering together of the great waters of the ocean? And will it not be romantic to discover the traces of the ancient world before the time of Noah, in every hill and valley which you examine?

EDWARD.

This will, indeed, be romantic and interesting, though I am not sure I shall understand it so well as astronomy.

MRS. R.

On the contrary, I think Geology is, perhaps, better fitted for our limited comprehensions than astronomy; for it is more within our each t
mine the structure and f
than that of the
easier to br

tive littleness of the earth at its creation, than to let our thoughts travel abroad through the boundless fields of infinite space. When we descend to the earth, we feel ourselves more at home; we are not so overpowered by sublimity as in the contemplation of astronomy; we can think more calml and reason more at ease; and we can trace the finger of God more visibly, perhaps, because more nearly.

EDWARD.

You may permit me to say, however, that, in studying astronomy, we can see the continual changes caused by the revolution of the planets and their satellites; but I cannot imagine that you can see such changes in mountains, rocks, and valleys.

MRS. R.

No, my dear; but we can infer from their appearances, by examining them carefully, that they have been sub[illegible]ometimes to chemical and [illegible] m[illegible]al changes, either lately or [illegible] and, as we proceed with our [illegible] have many examples

EDWARD.

You mentioned, a little time ago, that Geology is a new science: now, I think that is strange, for philosophers must always have observed the appearances of mountains and valleys, and it is their business to explain, or at least endeavour to explain, whatever they observe.

MRS. R.

Yes; but philosophers, till within the last few years, were more anxious to go upon what they fancied, than upon what they saw; and to contrive systems and theories, than to examine facts; and the consequence was, that there were many *Theories of the Earth*, as they were called, but these cannot with much propriety be looked upon as Geology:—that, like other sciences, must be founded on fact.

EDWARD.

But there must have been some grounds, at least, for these theories of the earth—something plausible or interesting; otherwise nobody would have attended to them.

MRS. R.

That I shall leave you to determine, after hearing the nature of a few of them. Burnet, the first of the theorists worthy of notice, says that, before the Deluge of Noah, the earth consisted of a light crust or shell, of uniform thickness, with the waters of the sea under it; that there were no mountains, no valleys, but one smooth unvarying surface over the whole earth; and that this crust, being broken up at the Deluge, formed the rocks and mountains as they at present exist.

EDWARD.

I think this is all very plausible, for it is said in Genesis, "that the fountains of the great deep were broken up!"

MRS. R.

But it is no where said that before the Deluge there were no rocks, mountains, nor valleys.

CHRISTINA.

If it was so, the earth must have looked a sad melancholy flat; Salisbury Plain is quite enough of such a landscape. Burnet, I should think, would have made a very sorry poet.

MRS. R.

On the contrary, his book is highly poetical, and is now read on that account alone. You may remark, that there could have been no rivers in this smooth mountainless world, for water cannot run unless there be a declivity.* Burnet, indeed, saw no use for water before the deluge, for there was no rain, he says, in these antediluvian times. I dare say, Edward, you will be more pleased with Woodward, whose theory undertakes to explain how shells became imbedded in marble and other rocks.

EDWARD.

That is precisely what I long so much to understand.

MRS. R.

Woodward says, the deluge was caused by all the solid parts of the earth dissolving and forming a paste, among which the sea-shells were mingled, by the agitation which then took place.

EDWARD.

But how were the rocks dissolved? I should

---

* See Conversations on Natural Philosophy, Conv. XI.

like to know what it is that could destroy their cohesion.

MRS. R.

Woodward says that the powers of cohesion among minerals was suspended, so that their parts no longer adhered firmly together; but he has no other authority for this than his own fanciful conjectures: so, Edward, you must lay your account for a little disappointment; and, as you are fond of astronomy, I shall console you with an account of the theories of the earth derived, or partly derived, from it.

EDWARD.

I cannot perceive what connexion there can be between astronomy and the origin of rocks and mountains.

MRS. R.

Whiston, for example, supposed that the deluge was caused by the tail of a comet; Descartes and Leibnitz conceived that the earth was an old sun with its fire extinguished; and the celebrated naturalist, Buffon, fancied that a comet struck off a corner from our present sun, and this, being melted by heat, formed the earth, which is now gradually cooling.

EDWARD.

I see nothing improbable in any of these theories. I think they seem to be very ingenious.

MRS. R.

You will admit, however, that ingenious as they seem, they are not supported by facts; and, in philosophy, we should not build systems on mere conjecture: such as that of De Marschall, who thinks all the rocks and the mountains have been produced by meteors, and have fallen at different times from the sky; and the shells in the marble being of different species from those of our present seas, he thinks, is an argument for their atmospheric origin.

EDWARD.

This seems to be very extravagant, indeed. I should like some more rational explanation.

MRS. R.

What would you think of the theory of Demaillet, who conjectures that the shell-fish themselves made the rocks, and that all animals, not excepting man, were inhabitants of the sea before

the fish had built the rocks high enough to stand above the water? The author tries to support this wild theory by referrring to mermaids. Lamarck, a disciple of the same school, says that the vegetables first converted water into clay; but he forgets to tell us how the vegetables themselves were formed.

CHRISTINA.

I am afraid, mother, I shall never understand all these theories.

MRS. R.

It is not necessary, my dear, for they are all exploded now. I shall only mention one more, that of the great astronomer, Kepler, who considered the earth as being actually alive, with the waters for blood, and the rocks for bones; while metals, he thinks, from their bad smell, are caused by disease and rottenness in the rocks.

EDWARD.

I think we have had quite enough of these theories; I should like to hear some of the more scientific accounts, which, you have said, are founded on facts lately observed.

MRS. R.

It was the great fault, indeed, of all those theorists, that they were very little acquainted with the actual structure of rocks and mountains; for, if they had been, they must soon have discovered that their conjectures were contradicted by the facts.

EDWARD.

Who was the first to introduce this natural system?

MRS. R.

I am not quite certain, but I think we are chiefly indebted to Saussure and De Luc, two Swiss philosophers, who travelled over the Alps and other parts, examined carefully the appearances of rocks, and, instead of spending their time in composing theories, recorded and published the facts which they had ascertained. A similar path was successfully followed by Dolomieu, a distinguished French philosopher. A great deal was also done by men of talent, who were connected with mines; among whom the celebrated Germans, Lehman and Werner, are the most distinguished, and may, indeed, be justly called the founders of Geology. In our own country, Dr. Kirwan was the first who published a philosophical work on

the science, with the exception of Dr. Hutton, of whose opinions I shall have frequent occasion to tell you as we proceed.

EDWARD.

But, since Geology, as you say, is founded on a knowledge of the actual state of rocks, will it not be necessary for us to learn something of these, before we proceed?

MRS. R.

Undoubtedly, some knowledge of minerals is indispensable; but you may learn a great deal of Geology without being extensively skilled in mineralogy, as it is only the more common minerals that come under discussion. I shall, therefore, try to procure for you a little cabinet of the more important of these, and we shall begin our first lesson by examining a few of them.

CHRISTINA.

When will you get the cabinet, mother? I long to see it.

MRS. R.

Probably, to-morrow; and, in the meantime, as the day is fine, we shall go a botanizing; so get your boxes in readiness.

CONVERSATION SECOND.

GEOLOGICAL CABINET.

MRS. R.

Well, I have procured, as I promised, the cabinet of specimens for you, and I expect you will prove good scholars, and do me credit.

CHRISTINA.

I confess I am a little disappointed in the appearance of this cabinet. The collections of minerals which I have seen are all much finer than those plain-looking gray stones.

MRS. R.

True, my dear, but they were intended for a different purpose. What you have here are fragments of the great rocks which compose our hills and mountains, and form the crust of the globe,

so far as it has hitherto been examined. The minerals which you have seen in collections consist more of rare or fine specimens of gems, precious stones, and metals, that occur only in particular places, and are comparatively of less importance in Geology, though indispensable in mineralogy.

EDWARD.

I think I shall find it easy enough to learn all these. I know some of them already: here is sandstone, and marble, and flint, and the granite which they pave the streets with.

MRS. R.

Right, my dear; but examine a piece of this *Granite* more closely, and try to tell me what it is composed of.

EDWARD.

I see three sorts of stuff in it; one shining like silver, another white, and another red.

MRS. R.

Every granite rock consists of these three substaces in various proportions. The silvery one, called ***Mica***, is in the form of soft elastic scales, and in some sorts of granite is black, and in others

golden yellow, which has sometimes deceived the ignorant into the belief that it was gold, particularly when it has been rubbed off from the rocks, and mixed with the sand of mountain brooks. It is this which forms the fine sand used for writing; and, in Russia, pieces have been found large enough to be used instead of glass for windows, and with this advantage, that they are not brittle like glass, and will yield rather than break.

EDWARD.

I wonder how granite is so hard and durable, when it has so much of this soft material, mica, in it.

MRS. R.

The hardness arises from the other two materials, quartz and felspar. The *Quartz* is, in this specimen, of a white colour, but it is sometimes red, brown, yellowish, and even colourless and transparent. You may always know it, from the glass-like surface of the broken pieces; while the *Felspar* is more splintery, and, for the most part, in pieces of a longish shape.

EDWARD.

I think I now understand the composition of

granite; but does it never contain any other materials, besides felspar, quartz, and mica?

MRS. R.

Frequently there are other minerals mixed with granite, but these are only considered as accidental: for instance, this specimen, you perceive, Christina, is studded with *Garnets.*

CHRISTINA.

What, those black-looking things! If these are garnets, they must be very inferior ones.

MRS. R.

You are right, my dear: these are not the precious, but common garnets, though the finest garnets seldom look any better than these till they are polished.

EDWARD.

Are these pieces of gold in this other specimen?

MRS. R.

Oh, no! you should recollect the old proverb; "All is not gold that glitters." These are composed of iron, combined with sulphur, and are

called *Pyrites*. Tin ore, copper, and other minerals, are also sometimes found in granite rocks, as well as in most of those which we shall now examine.

CHRISTINA.

Is this a piece of granite, mother? I think I can see the three sorts of things in it, and yet it is not quite like the other pieces.

MRS. R.

That is not called granite, though it does consist of the same three materials. Geologists call it by the German term *Gneiss*, but I think it would be better to call it *Granite Slate*, for it differs from granite chiefly in being of a slaty structure, in consequence of its containing a greater proportion of mica, and less quartz and felspar; the two last of which are usually in small grains, and not so distinct as in granite.

CHRISTINA.

May we always call it *granite slate?* I am afraid I shall not be able to remember that strange German word.

MRS. R.

Amongst ourselves we may call it granite slate; but you should also remember, that all the Geologists call it *Gneiss;* and you will not understand either geological books, when you come to read them, or geological conversations, should you chance to hear these, unless you are acquainted with the ordinary terms used in the science.

EDWARD.

Oh! here are garnets again, and gold-coloured pyrites, in this piece of slate. Is this also granite slate, mother?

MRS. R.

No, my dear, that is called *Mica Slate,* and frequently *Micacious Schistus;* the word schistus being German for slate. It wants, as you perceive, the felspar of the gneiss, and has only the mica and the quartz. Garnets are very commonly found in it, and occasionally felspar, but mica always predominates.

CHRISTINA.

What kind of slate is it that we see on the

roofs of houses? I think it is not like either mica or granite slate.

MRS. R.

That is called *Clay Slate, Argillaceous Schistus,* and sometimes *Ardesia,* or, as the French say, *Ardoise.* It is one of the species of this slate that is smoothed for writing on at school, and other species are used as whetstones, &c. Many of the mines, from which are dug the ores of copper, lead, tin, silver, gold, and quicksilver, are situated in clay-slate rocks.

EDWARD.

Are those all the sorts of slate?

MRS. R.

No: besides these, there are *Flinty Slate,* and *Chlorite Slate,* which is, as you see here, of a green colour, and *Hornblende Slate,* which we shall now examine.

CHRISTINA.

Oh! this hornblende slate has black felspar in it.

MRS. R.

For once you are mistaken, Christina. What you take for black felspar is hornblende, which is usually of a dark bottle-green colour, while felspar is commonly reddish. Besides, hornblende is in longer pieces, and they often, as you see, cross one another, which is not the case with felspar. This slate is chiefly composed of hornblende, though you may see here and there a speck of mica in it, and two or three bits of reddish felspar.

EDWARD.

I think that this hornblende is also more shining and glassy than felspar.

MRS. R.

Yes; and it is still more so in this specimen, which is called *Hornblende Rock,* and which, as you perceive, is not slaty. The hornblende is also a principal material in two other rocks, of which here are specimens. This one is called *Green Stone,* and contains a large proportion of hornblende, with a considerable quantity of felspar intermixed. Some of the greenstone rocks are of a slaty structure, and are then said to be of green-

stone slate. The other specimen is called *Sienite*, from its being found in the quarries of Siena, in Egypt. It differs from greenstone, in having a greater proportion of felspar, and a smaller quantity of hornblende, and it is usually of a red colour, while the other is greenish or gray.

CHRISTINA.

I should have taken that piece of sienite for granite.

MRS. R.

Sometimes, indeed, it has been called Egyptian granite, and this specimen is a chip from Pompey's Pillar at Alexandria; but, if you examine it, you will find no quartz nor mica, which there should be to constitute granite. The only substances are red felspar and dark bottle-green hornblende. It will be proper for you to know that these rocks, which contain a large proportion of hornblende, are called by Geologists *Trap-Rocks;* the word trap being the Swedish term for a stair, the form of which trap-rocks usually resemble.

CHRISTINA.

This next specimen, if I mistake not, is *White Marble?*

MRS. R.

It is; but Geologists seldom use the term marble, which they leave to statuaries, and prefer limestone. This white sort they call ***Primitive Limestone***, from an idea that it was formed before what is called *Secondary Limestone*. You will find that these terms, primitive and secondary, will be of great importance as we proceed. But it is only necessary for you at present to remember, that primitive means *older*, and secondary *newer*; the greater number of rocks are arranged under one or other of these divisions.

EDWARD.

I cannot imagine in what manner it could be discovered that one rock is older than another.

MRS. R.

If you were to find the wall of a house widely rent from top to bottom, and another wall carried right through the rent, would you not think it very clear that the rent wall was older than the other that crossed it?

EDWARD.

Certainly; but there is nothing like this among rock.

MRS. R.

You mean so far as you know; for you will find that this is one of the most common occurrences, and is familiar, not only to learned Geologists, but to illiterate miners, as we shall see while we proceed.

CHRISTINA.

I think this specimen better deserves the name of greenstone, than the one we were examining a little time ago.

MRS. R.

It is not, however, called greenstone. The name is taken from those beautiful waving lines of white and red, which run through its substance. It is called *serpentine*, and, when it is intermixed with limestone, as you see it in this specimen, it forms the valuable stone called *Verd Antique*. As serpentine lake has a fine polish, it is frequently used for ornaments, in the same way as marble and alabaster.

EDWARD.

I think these look like pieces of felspar, scattered through this next specimen.

MRS. R.

Quite right: and I am glad to perceive that you begin to know some of the materials of the specimens. This is called *Porphyry,* because it is usually of a red colour; but Geologists call every rock porphyry, where crystals are scattered through a mass of other matter, as in the instance of this specimen, where crystals of felspar are scattered through a mass of *Hornstone.*

CHRISTINA.

I see no crystals here, mother; you surely do not call these little square things crystals? They do not shine in the least.

MRS. R.

I must again remind you, my dear, of the proverb I quoted yesterday, that "all is not gold that glitters;" for it is not necessary that a crystal should be shining or transparent; but that it should be of a very regular figure, and appear as

if it were cut or polished: sugar-candy, for example, is in crystals, and Epsom salts, before they are melted, which are of a longish square form, somewhat like those very crystals of felspar in that bit of porphyry.

EDWARD.

Are these also felspar crystals in this other specimen?

MRS. R.

No: those are crystals of quartz, and the mass through which they are scattered is felspar not crystalized. This rock is also called porphyry, from the circumstançe of the crystals; and, if the mass of the rock were clay and crystals, either felspar or quartz, or both, it would still be called porphyry.

EDWARD.

If the felspar or quartz were in round pieces, and not in square crystals, would the rock in that case be called porphyry?

MRS. R.

No: in this specimen, as you perceive, there are round pieces of greenish stone scattered through the substance of this gray clay-stone; and, from the resemblance of these to almonds, this rock,

and all others of the same appearance, whatever the difference of their materials may be, are called *Amygdaloid.*

EDWARD.

This next specimen appears to me very like the slate which we were examining a little while ago.

MRS. R.

It is, however, as you will observe by looking more closely at its structure, very different: it is composed chiefly of clay-slate, or ardesia mixed with particles of sand, and is conspicuous in geological books for its German name of *Wacké;* or, more commonly, on account of its colour, *Gray Wacké.* It has not so often the structure of slate, as of masses of no determinate form, constituting large rocks and mountains.

EDWARD.

Since this wacké is composed of sand, as you have told us, it might as well be called sandstone, I think.

MRS. R.

The name *Sandstone* is confined to rocks which are considerably different, being wholly

composed of sand, and not part sand and part clay-slate, as in wacké; besides, sandstone is generally red, reddish brown, yellow, or whitish, and sometimes spotted or striped with these colours; rarely, if ever, of the blueish gray colour of wacké, as you may perceive in these specimens.

CHRISTINA.

I see little specks of something like silver, in this specimen of sandstone.

EDWARD.

Oh, that is mica, evidently; but I am at a loss to know how it comes to be in sandstone.

MRS. R.

You will learn all that as we proceed; but what say you to the other materials of the specimen? Look closely at it, and see if you know what the sand itself is composed of.

EDWARD.

I think it appears to be little particles of quartz, all broken down and hardened together.

MRS. R.

You are right; almost all sand is composed chiefly of quartz, and the sand in sandstone is particularly so.

CHRISTINA.

What is this large odd-looking specimen called? I should be apt to name it plum-pudding stone, for it looks exactly like a Christmas pudding.

MRS. R.

Sometimes it is called so, but the Geologists usually call it *Conglomerate,* though sometimes *Breccia:* it is composed, as you see, of a mass of sandstone, inclosing round pieces of limestone, quartz, and most other sorts of stones. It is considered to be a very important rock for explaining the systems of Geology.

EDWARD.

This specimen appears to be chalk, though it is not altogether so white.

MRS. R.

No, my dear: that is *Gypsum,* or plaster of Paris; or, as you are something of a chemist, you

may know it under the name of sulphate of lime, it being composed of sulphuric acid and lime; while *chalk*, you know, as well as marble and limestone, are termed by chemists carbonate of lime, from being composed of lime and carbonic acid.

CHRISTINA.

I see some pieces of flint in this chalk; do you call it, on that account, a conglomerate, like the plum-pudding stone we were just examining?

MRS. R.

No; the flints in chalk do not render the rock a conglomerate.

EDWARD.

Ah! here are shells in this limestone, like those in the marble of the chimney-piece. Has this specimen any particular name?

MRS. R.

When shells occur in a rock of this kind, it is usually called shell limestone; and it is considered to be of great moment in geological discussions.

CHRISTINA.

What a sombre-looking specimen is this! and

it is well-placed, I think, beside this piece of coal.

MRS. R.

The sombre-looking specimen is called *Basalt*, which forms some of the most singular rocks in nature: such as the Giant's Causeway, in the north of Ireland; Fingal's Cave, in the Island of Staffa; besides many romantic cliffs and mountains in various other parts.

EDWARD.

Is that a crystal of hornblende in it? I think it resembles what we were examining.

MRS. R.

Yes, that is *Hornblende;* but the other crystals which you see here are different: this one is called *Angite,* and this other *Olivine.* It will be proper for you to remember these, as they are frequently referred to in discussing the origin of basalt.

EDWARD.

This specimen, I should suppose, you call slate basalt, as it has a very similar appearance?

MRS. R.

No: that is called *Shale,* and sometimes *Slate-Clay,* to distinguish it from the clay-slate which we have already examined. It is usually found in connection with *coal,* and containing the remains of plants as well as shells.

EDWARD.

Well, I should like to know something more about this shale; and the coal, too, must be interesting, since it is so useful to us.

MRS. R.

We shall have a great deal to tell you about the origin and formation of coal, when I come to explain the several systems of Geology.

CHRISTINA.

Here are two pretty pieces of square crystal; you do not surely call these rocks?

MRS. R.

Not rocks, when they are in such small pieces; but one of those often forms considerable masses. If you touch it with your tongue, I dare say you will be able to say what it is.

CHRISTINA.

Oh, it is quite salt: I thought it was hard, like crystal.

MRS. R.

That is *Rock Salt,* which is also an important substance in systems of Geology; the other is crystal of *Calcareous Spar,* as it is called, and is composed of lime.

EDWARD.

Are these all the rocks which we have to know in studying Geology?

MRS. R.

These are all that are properly called rocks; but, besides these, you should be acquainted with the substances that usually cover the surfaces of rocks, which are called *Alluvial* substances: such as gravel, clay, sand, and the round stones of all sizes which are found scattered over the ground, called, by Geologists, *Bowlder-stones;* but all these you will become best acquainted with as we proceed: when we shall see, also, how gravel, sand, clay, and bowlder-stones, are formed from the original rocks; and how even some of the

newer rocks themselves are formed from the older ones. In the meantime, you must spend a day or two in going over your specimens in the cabinet attentively; and, as soon as you know them well, I shall tell you something of the wonders of Geology.

EDWARD.

But, may I ask, mother, if the rocks are always placed in the same order as they are here in the cabinet: granite first, gniess second, mica-slate third, and so on?

MRS. R.

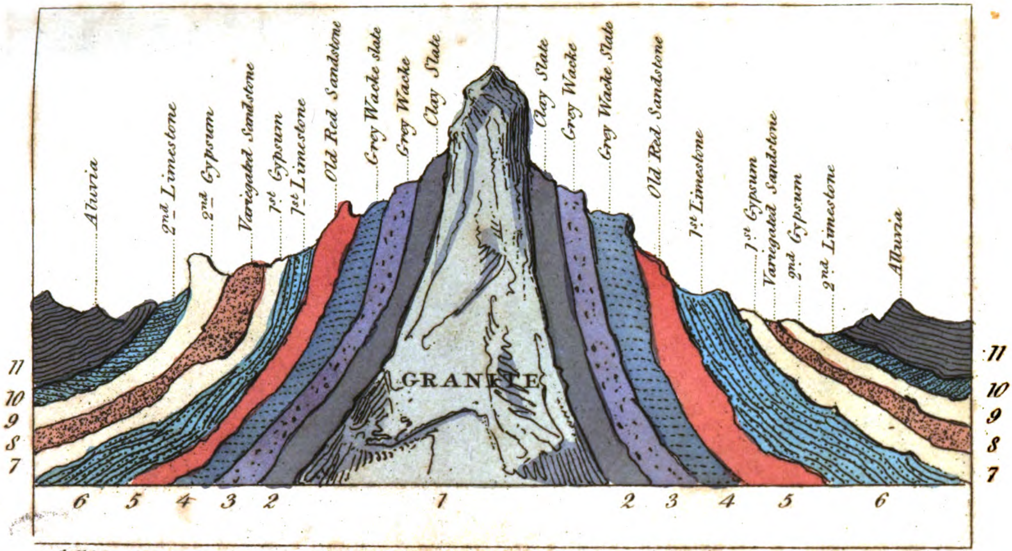
The reason, my dear, of placing them in this order, is, that granite is in nature usually found to lie the lowest; and upon it, as a foundation-stone, gniess, mica-slate, and the other rocks, are seen to rest; for the most part, in the same order as they are placed in the cabinet.

EDWARD.

They are not always, then, to be found in the same order? I fear that will be rather puzzling to us in understanding them.

MRS. R.

When Geology began to be studied, it was sup-



WHB f[t] Section of the **BROCKEN MOUNTAIN**, in Hartz Forest, Germany.

posed that the order of the rocks was pretty uniform; but many exceptions were soon discovered. The gniess, for example, is often wanting; and the granite is covered with mica-slate, hornblende rock, or with limestone or porphyry. One thing is worth your observation: as granite is the lowest, or foundation-rock, it is for the same reason the highest, and forms the summit of many of the highest mountains.

EDWARD.

I confess I cannot understand that; for, if it be the foundation of the other rocks, it ought to be covered and concealed by them.

MRS. R.

It would be so, undoubtedly, were all the rocks placed horizontally, as you would lay one book over another on a table; but granite, gniess, mica, and clay-slate, hornblende rock, sienite, greenstone, and some of the others, are placed almost on end, so that the granite, which is the lowest at one end, is the highest at the other, as you will understand by placing a few books perpendicularly, and others resting on them, to represent the different rocks.

EDWARD.

But, if I were to continue to add book after book, each resting on the one before it, they would at last lie horizontally, and parallel with the table; is it so with rocks?

MRS. R.

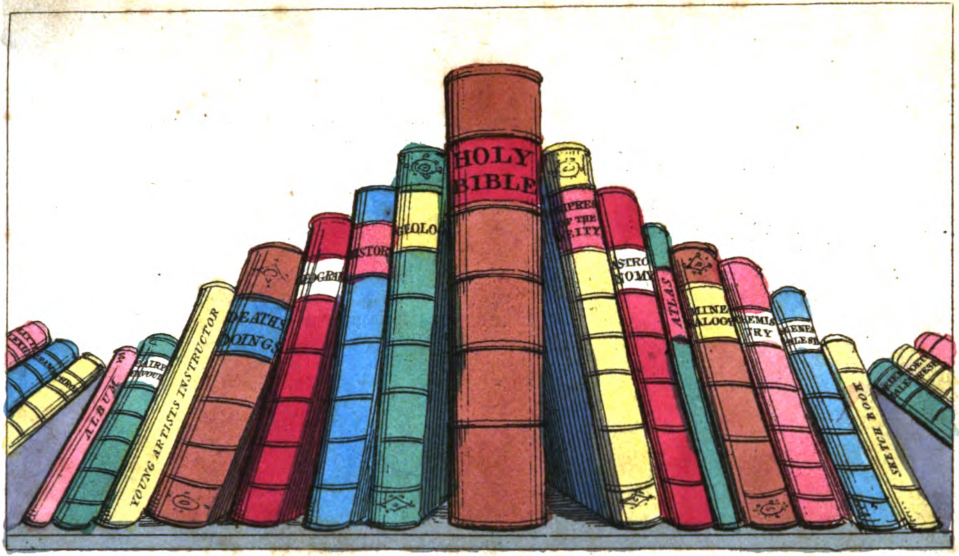
Precisely so. The granite is generally perpendicular, or nearly so; and the gniess, and the other rocks that more immediately rest on it, are found at high angles; while the gray wacké, the conglomerates, and the sandstone, are at low angles; and the basalt, shale, coal, but more particularly the alluvial substances, gravel, sand, and clay, lie horizontally.

CHRISTINA.

See, here is a whole range of books, according to what you have just told us; the granite standing high and perpendicular, and the other rocks all following in their order. [See plate.]

MRS. R.

This will so far assist you to understand the po-



COMPARATIVE GEOLOGY.

Or a Familiar method of illustrating the Vertical and lateral Positions of Rocks.

newer rocks themselves are formed from the older ones. In the meantime, you must spend a day or two in going over your specimens in the cabinet attentively; and, as soon as you know them well, I shall tell you something of the wonders of Geology.

EDWARD.

But, may I ask, mother, if the rocks are always placed in the same order as they are here in the cabinet: granite first, gniess second, mica-slate third, and so on?

MRS. R.

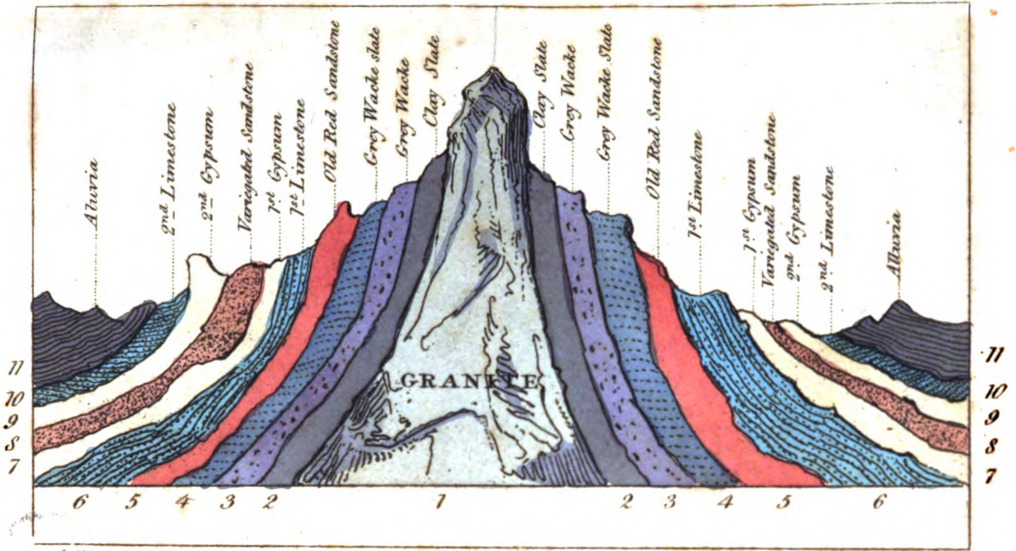
The reason, my dear, of placing them in this order, is, that granite is in nature usually found to lie the lowest; and upon it, as a foundation-stone, gniess, mica-slate, and the other rocks, are seen to rest; for the most part, in the same order as they are placed in the cabinet.

EDWARD.

They are not always, then, to be found in the same order? I fear that will be rather puzzling to us in understanding them.

MRS. R.

When Geology began to be studied, it was sup-



WHB ft Section of the BROCKEN MOUNTAIN, in Hartz Forest. Germany.

posed that the order of the rocks was pretty uniform; but many exceptions were soon discovered. The gniess, for example, is often wanting; and the granite is covered with mica-slate, hornblende rock, or with limestone or porphyry. One thing is worth your observation: as granite is the lowest, or foundation-rock, it is for the same reason the highest, and forms the summit of many of the highest mountains.

EDWARD.

I confess I cannot understand that; for, if it be the foundation of the other rocks, it ought to be covered and concealed by them.

MRS. R.

It would be so, undoubtedly, were all the rocks placed horizontally, as you would lay one book over another on a table; but granite, gniess, mica, and clay-slate, hornblende rock, sienite, greenstone, and some of the others, are placed almost on end, so that the granite, which is the lowest at one end, is the highest at the other, as you will understand by placing a few books perpendicularly, and others resting on them, to represent the different rocks.

EDWARD.

But, if I were to continue to add book after book, each resting on the one before it, they would at last lie horizontally, and parallel with the table; is it so with rocks?

MRS. R.

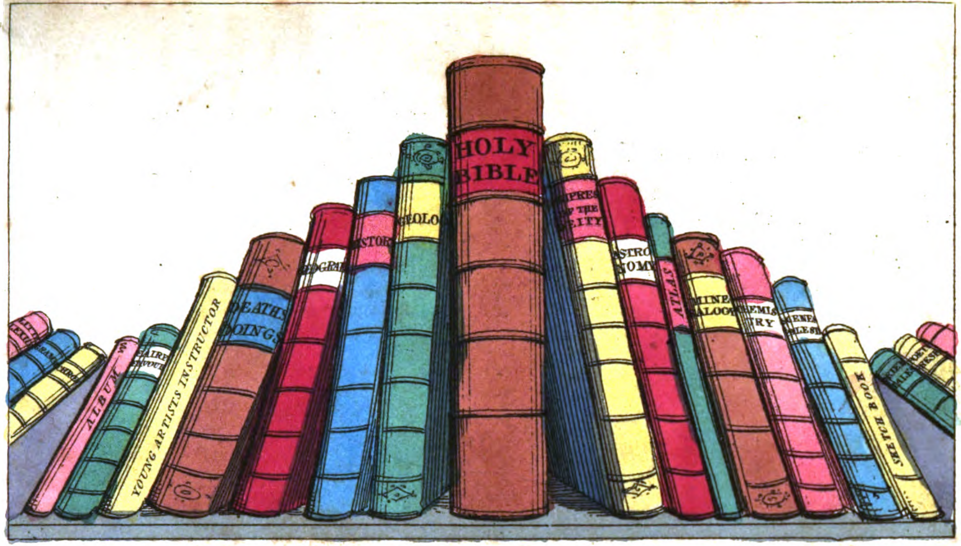
Precisely so. The granite is generally perpendicular, or nearly so; and the gniess, and the other rocks that more immediately rest on it, are found at high angles; while the gray wacké, the conglomerates, and the sandstone, are at low angles; and the basalt, shale, coal, but more particularly the alluvial substances, gravel, sand, and clay, lie horizontally.

CHRISTINA.

See, here is a whole range of books, according to what you have just told us; the granite standing high and perpendicular, and the other rocks all following in their order. [See plate.]

MRS. R.

This will so far assist you to understand the po-



COMPARATIVE GEOLOGY.

Or a Familiar method of illustrating the Vertical and lateral Positions of Rocks.

sition of rocks; but I must caution you against supposing all rocks to be flat, like the books: for, though the slaty rocks, sandstone, coal, and others, are flat and pretty uniform, yet granite, sienite, basalt, &c., for the most part, are in great shapeless masses, or *amorphous*, as the Geologists say when a rock has no determinate form.

CONVERSATION THIRD.

SYSTEMS OF GEOLOGY.

EDWARD.

Mother, we have been very diligent in studying the specimens in the cabinet, and Christina says she knows them all.

MRS. R.

Very well: we shall then proceed to the systems of Geology, and I shall give you your first lesson now, if you are still desirous of learning it; for my labour will be all in vain, and your time will be lost, if you have no wish to know the science.

EDWARD.

Oh, we are more anxious to go on than ever, since we began to know something of the different sorts of rocks. But, mother, you talk of *systems*

of Geology; now I imagined from the first that there was only one system: I fear I shall never be able to master a number of them.

MRS. R.

Geology, my dear, is, as I told you before, a new science; and, as much of it appears to be still founded on speculation, this has given rise, among ingenious men, to more systems than one: in the same way, as you have already seen, that there were more than one theory of the earth, when theory was more in fashion than the examination of facts.

EDWARD.

Then, the systems of Geology which you are speaking of may be considered, I suppose, to be so many theories of the earth, founded more upon facts actually investigated than any former theory of the same kind?

MRS. R.

Precisely so: for example,—the VULCANISTS, as they are quaintly called, think that the facts indicate *fire* to have been the chief agent in forming rocks; while the NEPTUNISTS, their opponents,

think they have as good evidence, if not better, to prove *water* to have been the chief agent.

CHRISTINA.

Are these two, then, all the systems of Geology now in credit? It will be very amusing, I dare say, to hear this double history of the origin of rocks.

MRS. R.

Till within a few years, these two have been the prevailing systems; but another has lately appeared, which seems likely, I think, to supersede them: it is called by Mr. Granville Penn, who is its great champion, the MOSAIC GEOLOGY, because it is chiefly derived from the Mosaic History of the Creation and the Deluge.

EDWARD.

You told us before, that some of the old theories of the earth were taken, or pretended to be taken, from the narrative in the Scriptures; and, as these theories were so very erroneous, is there no danger of losing ground again by pursuing this course?

MRS. R.

Not at all, so long as the Mosaic Geology can

find such advocates as Mr. Penn, who is extensively acquainted with the facts and theories of the modern *Mineral Geologists,* as he calls all those who are not his own disciples. I am certain you will be pleased with his system; for it is no less ingenious than probable, and will give you much more sublime views of the creation than are to be found even in the inspired poem of Milton; and that is saying a great deal.

EDWARD.

But, if this system be so very superior as you seem to think it, why should we take the trouble to learn the others?

MRS. R.

For several reasons, it will be necessary to know something of the two great systems of the Neptunists and Vulcanists. The Mosaic Geology is so recently published, that, though it has made some noise, it cannot be looked upon as established; and, unless you know something of the other systems, you cannot so well understand the Mosaic, nor see its beauties: besides, you will learn many interesting facts respecting the powers

of fire and water, which are brought into the several discussions.

CHRISTINA.

I am sure I shall like the water theory; for I have had a liking to water, ever since I read the delightful romance of Undine.

EDWARD.

Fire, however, you will confess to be the more terribly sublime element. The overflowing of the Nile is nothing to an eruption of Ætna or Vesuvius.

MRS. R.

It would be more correct to say, that the degrees of sublimity in the action of the two elements cannot be well compared, on account of their dissimilarity; though, in geological discussions, they come into nearer resemblance than might be anticipated: Werner's Rise and Fall of the Primeval Waters, and Hutton's Increase and Quiescence of the Subterranean Fires, will lead us to many singular conclusions.

EDWARD.

You did not mention either of those names before.

MRS. R.

They are, however, the most distinguished names in Geology: Werner was Professor of Mineralogy at Theyberg, in Saxony; Dr. Hutton was Mathematical Professor to the Royal Military Academy, at Woolwich. Werner had more practical knowledge than Hutton; but he was too precipitate in concluding that all the rocks in the world were exactly like those of Saxony, for it would have been almost as near the truth to have concluded that all the nations of the world had light hair, blue eyes, and fair complexions, like his countrymen.

EDWARD.

Then, I suppose, Dr. Hutton would avoid this evident error in his system.

MRS. R.

That you may immediately see, from the short outline I shall now give you of the Huttonian Theory. For the purpose of making a globe like the earth, with seas, continents, and islands, diversified with hills and valleys, and productive of food for various animals, Dr. Hutton considered it as indispensable that other globes should have

previously existed, from which materials for the structure might be derived.

EDWARD.

But how does he come to know that there were such globes?

MRS. R.

He imagined that they *must* have existed, because, as he thinks, the earth could not have been made without them; and, if we agree to this, he then tells us, that those former globes, being acted upon by the moist atmosphere, by rains, and by the frosts and thaws of winter and spring, would, in a long course of years, be crumbled down, or, as the Geologists say, ***disintegrated;*** and gradually carried by rivers, in the form of sand, clay, and gravel, to the sea. At the bottom of the sea, these materials would arrange themselves in beds,—differing in thickness according to the circumstances by which they might be affected.

EDWARD.

All this might be, and yet I do not perceive how such soft materials would form hard rocks of granite and basalt.

MRS. R.

You are right; those beds would have continued in the soft state of sand or clay for ever, unless something occurred to harden them. It is here that Dr. Hutton brings in the agency of fire, and tells us, that there is at the bottom of the sea sufficient heat, from a great central fire which he conceives to exist in the centre of the globe, to melt all the clay, sand, and gravel, and to form them into rocks.

EDWARD.

However plausible this may appear to some people, to me it is far from being even probable; but, though it be granted that rocks are thus formed at the bottom of the sea, it does not explain how the rocks on the land are formed

MRS. R.

According to Dr. Hutton, all the rocks, both on the land and in the sea, were formed in the same way at the bottom of the ocean; and he provides for their appearance above water, by supposing that the central fire occasionally expands itself, and elevates the newly-formed rocks into islands and continents, diversified by hills and valleys; these being destined, in their turn, to the same

changes of destruction and renovation, as those from which they took their origin.

EDWARD.

When bathing in the sea, I have always felt it very cold at the bottom; but, according to this account, it ought to be hot enough to melt sand and other substances into the form of rocks.

MRS. R.

Dr. Hutton's central fire is not supposed to act so much on the sand newly spread over the bottom of the sea, as on the older beds, which are deeper, and consequently more exposed, from their nearness, to the force of its heat. Besides, the existence of volcanos, most of which are near the sea, is a strong proof of the existence of subterranean fires.

EDWARD.

Then why are there not more volcanos in different parts of the world? We have none in this country, and it might as well be said, that occasional thunder-storms prove the air to be always overcharged with electricity, which is the same kind of reasoning you were a little while ago blaming Werner for using. Then I should like to

know why Dr. Hutton confines all the effects of his heat to the beds of sand at the bottom of the sea; for, if the fire is central, it ought to act on the land as well.

MRS. R.

You are very difficult to be satisfied, I think, Edward: the reason, however, I may tell you, why Dr. Hutton refers the chief action of heat to the bottom of the sea, is, that the beds of sand are lower, and much nearer the central fire; yet, even on land, there is good evidence of subterranean heat, in the hot springs which are found in various parts of the world; and, in this country, at Bath, Buxton, and other parts. Even cold springs are often, in winter, of a higher temperature than the air; and this is the reason that many of them never freeze during the hardest frosts.

CHRISTINA.

Oh, and you forget, Edward, what we learned in chemistry about the conductors of heat; for, if there is a non-conductor between the central fire and the bottom of the sea, very little heat will get through. You may recollect that, when we visited the glass-house, we could stand quite near the furnace, from the heat being intercepted by the

brick-work; and I think it may be the same with rocks.

MRS. R.

I may tell you, also, that the surface of burning lava from a volcano may often be walked upon with impunity, while the melted matter is only covered with a crust a few inches in thickness; but, though all this be true, it does not by any means follow that the existence of Dr. Hutton's central fire is proved.

EDWARD.

I should like to know, also, what caused the central fire to throw up in confused masses the rocks which it has just formed from the materials at the bottom of the sea.

MRS. R.

The Huttonians seem to consider partial operation as one of the peculiar characteristics of their central fire; though it appears to be very strange and unaccountable, that the fire which raised the continents, with their mountain masses, from the bottom of the sea, should have remained inactive while such masses were placed in contact with it; and it appears to be inconsistent with all we know of fire, that it should elevate high mountains by expansion, and then quietly permit them to be

crumbled away by rains and frosts, and the materials deposited to an immense thickness, while its expansive force is not exerted till the worn-down continents are in danger of inundation, from coming on a near level with the sea. I have always thought it much more reasonable to suppose the expansive power to maintain the mountains at the same elevation, by raising them from below, in proportion as they become lower by the wearing-down of their surfaces; and that the same power would operate more readily in raising their light beds of chalk or sandstone from the bottom of the sea, than a mass of granite, basalt, and numerous other rocks, of incalculable weight and immeasurable thickness, as Dr. Hutton supposes.

EDWARD.

Then it would appear that the expansive power of the central fire does not act equally on the rocks that are under, and those which are above water; for, if it acted equally, *new* continents could never be raised from the waters, nor *old* ones be immerged in the waters, as a level would be uniformly maintained.

CHRISTINA.

How does Dr. Hutton imagine that the great

central fire is kept burning? It would require, I should think, a mass of coal, or other fuel, quite incredible.

MRS. R.

That is a subject which the doctor did not think proper to say much about; but his eloquent disciple and defender, Professor Playfair, takes it up, though not, I must confess, in the most satisfactory manner. The usual sources of heat are the sun, combustion, percussion, friction, and chemical combination; but Mr. Playfair says, the central fire is not generated in any of those ways, for in the central parts of the earth there could be no combustion, and that an explanation cannot fairly be expected of the maintenance of heat under circumstances so different from ordinary experience. Besides, says he, we may as well be called upon to explain the origin of the sun's heat, which nobody has hitherto been able to do.

EDWARD.

This is certainly a very plausible excuse; and I should like to hear one equally plausible for an objection which has just struck me. You say, Dr. Hutton maintains that the rivers are continually carrying down additions to the beds of sand and

gravel at the bottom of the sea; but, if this were so, the waters of the sea would be continually rising, and encroaching on the land. I have, indeed, read of Calicut, and some other parts, that have been inundated by the sea; but I have also seen accounts of the sea retiring from the land, which does not correspond well, I think, with Dr. Hutton's system.

MRS. R.

This objection has been often made, and was never, that I have seen, satisfactorily answered. With respect to the city of Calicut, which was the admiration of the Europeans who first went to India, it is now nearly four miles overflowed by water, and ships sometimes strike on the tops of the steeples. In ancient times, the towns of Olenus and Helice, in Achaia, suffered a similar fate, not long before the battle of Leuctra; but such instances as these rarely occur: they are by no means so common as Dr. Hutton's theory would lead us to expect.

EDWARD.

Altogether, then, I think Dr. Hutton has not clearly established these parts of his system.

MRS. R.

You will be better able to judge of that, when you afterwards hear, in detail, the proofs, and the curious facts which he brings from the observation of rocks, as they now exist; and when you compare these with the water-system of Werner, which I shall next explain to you: but, not to puzzle you too much at one time, I shall reserve that for our next lesson, and leave you to talk over by yourselves the few things which I have now told you.

CHRISTINA.

I shall go, I think, and write down some of the principal things, as I shall then both understand and remember them better.

MRS. R.

That, as I have often told you, is indeed the most effectual way of learning a science.

CONVERSATION FOURTH.

FIRST PRINCIPLES OF THE WERNERIAN SYSTEM.

EDWARD.

UPON considering the system of Dr. Hutton as you explained it to us, it occurs to me that it is necessary for him to explain the origin and formation of the other globes from which the present earth was formed, as well as of the present earth.

MRS. R.

Dr. Hutton himself did not think so when the objection was made; and it is not, in my opinion, good philosophy to go on, after a probable cause has been assigned, to ask what was the cause of that cause; for, in this way, you would never arrive at any fixed point. Your darling study of astronomy, you are aware, might in this way be assailed, by asking what is the cause of gravity and

attraction, of which no satisfactory account has ever been given; and you might attack chemistry, by asking the cause of affinity, or the origin of electricity or galvanism, which nobody could tell you.

EDWARD.

True: we must, I know, stop somewhere in our inquiries; but I like to get to a probable resting-place, and not to say, with the Indian sage, that the earth rests on an elephant, the elephant upon a tortoise, and the tortoise on he knew not what, as Dr. Hutton appears to do.

MRS. R.

Then, I dare say you will be pleased with the system of Werner, who begins at the beginning, or PRIMITIVE FORMATION of the earth, or rather the crust of the earth.

EDWARD.

I shall be pleased if he satisfy me that he knows what took place at this primitive formation, but not otherwise.

MRS. R.

You shall hear: according to Werner, all the substances which now constitute rocks, mountains,

and soil, on the earth's surface, were originally existing in a state of solution in the waters of the great chaos, which he supposes, at the beginning, to have surrounded the globe to a vast depth. The substances or materials of rocks, thus swimming in the primitive ocean, he conceives to have gradually fallen to the bottom, sometimes by chemical, sometimes by mechanical means, and sometimes by both together; and in this manner he thinks all the rocks have been formed which we now find, on digging into the earth. The inequalities of mountains and valleys on the surface of the earth, which were thus produced as soon as the waters began to subside (and this subsidence is an important point in the system), gradually rose out of the primitive sea, forming the first dry land. The rocks which were in this manner first formed, Werner calls the *Original*, or *Primitive Formation;* they consist of granite, gneiss, different species of slate, marble, and trap.

The formation of these rocks, however, did not, it seems, exhaust the materials floating in the waters, for the deposition went on, and a class of rocks were formed, consisting of gray wacké, limestone, and trap, which rested on the primitive, and are called by Werner the *Intermediate* or

Transition Rocks; because, on their appearance above the water, the earth, he conceives, *passed* into a habitable state. After the formation of these primitive and transition rocks, Werner alleges that the water suddenly rose over them to a great height, covering them in many places, as it again subsided with a new formation of rocks, consisting of sandstone, conglomerates, limestone, gypsum, chalk, and rock salt, which he called *Level* or *Floetz Rocks.* Since that period, the wearing-down of the rocks, by the action of the weather and other causes, and the washing-away of the worn materials by rains and streams of water, have formed soil, gravel, sand, peat, and the various other beds which are called *Alluvial.* Such is an outline of the celebrated system of Werner, which has had more disciples than any former system of Geology.

EDWARD.

That is certainly one strong proof of its merit; but I like to satisfy myself of the truth of what I learn, independently of the authority of great names, and I am by no means clearas to the very first thing you mentioned as part of the system,—I mean the existence of the chaotic ocean of un-

known depth, and containing in solution all the materials of rocks. If there be no record of this, I cannot see what proof Werner can give of its existence.

MRS. R.

This objection has been very much urged upon Wernerians, and they reply, that "We may be, and are fully convinced of its truth, although we may not be able to explain it; for to infer from observation that an event really happened, is a very different thing from ascertaining how it actually did happen."

EDWARD.

This is not a fair answer; for some proof ought to be given of the existence of this great body of water, so immensely deeper than our present ocean, which, if I mistake not, Dr. Hutton is contented with as sufficient for his system.

MRS. R.

Werner argues, that we now meet with great masses of rocks in every part of the earth, whose origin and formation cannot be explained, except by supposing them to have been deposited from a solution of their materials in water; and, as it is chemically impossible that so extensive a solution

could have existed without a vast quantity of water, the great depth of the ocean must appear evident.

EDWARD.

This, I think, is a very ingenious argument; but it was, perhaps, taking too much credit to himself, to say that no other explanation *could* be given of the formation of rocks; for, though he could contrive no better, somebody else may. I should like to know, also, what became of all this "world of waters," after they had formed the original rocks.

MRS. R.

Werner, I believe, never gave any satisfactory account of the disappearance of the original waters; but his disciples have made various conjectures on the subject, such as supposing them to have retired to a great central abyss, or hollow, at the centre of the earth, formed by impenetrable walls of granite; others, that the earth was sent to afford them a retreat when they were no longer necessary.

EDWARD.

I think both improbable, for I cannot conceive that there would be sufficient space to contain them in any abyss which could be formed in the

interior of the earth; besides, if I comprehend the system, it maintains that the whole globe of the earth consisted, at first, of the great chaotic solution of the materials of rocks; and, if so, the supposition of an abyss is absurd.

MRS. R.

I have sometimes thought that the difficulty might be got over by supposing the water, after parting with its solution, to have been decomposed, and its component parts of oxygen and hydrogen to have been disposed of in the atmosphere. The low proportion of oxygen in the atmosphere seems at first to discountenance such a supposition; but, when you consider the quantities of oxygen which are contained in the several substances in the interior and on the surface of the earth, the opinion will not appear altogether imaginary; and this will be farther strengthened when you recollect that the specific gravity of the hydrogen carries it upwards, and that the higher regions of the atmosphere contain a much greater proportion of it than the lower.

EDWARD.

I think this is more probable than the retreat of

the waters into a central abyss, which seems to be still more fanciful than Dr. Hutton's central fire.

MRS. R.

A strong chemical objection has also been raised against Werner's universal solution of the materials of rocks; but I am not certain of making it sufficiently plain to be interesting to you, as it involves so much chemistry.

CHRISTINA.

I should like to hear it, at all events, for I can remember a system a great deal better after hearing objections to it and discussions about it.

MRS. R.

Yes: this gives an interest to points which you might otherwise look upon as unimportant. The objection to the universal solution is, that no solvent, so far as chemical experiment has yet ascertained, can retain so many substances in solution as are found to compose the crust of our globe; for there are nearly fifty simple substances which must, if the system be true, have all been held in solution at the same time, though not one fourth of these could be held in solution at the same in-

stant by any known solvent. Even admitting that the solvent powers of water may be much increased by being saturated with one or two particular substances, yet this is very limited, and increase of power seems often to arise from the action of one of the substances so held in solution upon the substance added, caused by the precipitation of the other components of the solution.

EDWARD.

Ay; but chemists tell us that we do not yet know how many simple substances there are, and say that, though recent discoveries have prodigiously multiplied the elements of nature beyond the old number of four, they think it probable that future discoveries may again reduce them to a very few.

MRS. R.

But what would you say to a great number of the substances composing rocks being altogether insoluble in water?

EDWARD.

I should think that it would be fatal to the system, if no explanation could be given of the solution.

MRS. R.

It has been said in reply to this objection, that though several simple substances, such as flint, and consequently quartz and felspar, which contain a large proportion of flint, cannot be dissolved in water by themselves, yet this can be readily accomplished when other substances are added to the water. Flint, for example, will not dissolve in distilled vinegar; but, if clay and flint be dissolved with an alkali, the precipitate thence produced will dissolve in the vinegar; and, when clay is precipitated from a solution by adding lime, an excess of lime will cause the precipitated clay to be again dissolved. Again: if you throw a piece of iron and a piece of slate-clay into water, neither of them will dissolve; but, if you take rust of iron, that is, iron combined with oxygen, it will both dissolve in the water and combine with the earth.

EDWARD.

Might not a similar objection be brought against Dr. Hutton's system, from the circumstance well known in chemistry, of all substances not being fusible? I think, if I mistake not, lime

is one of the substances which cannot be melted by heat, and flint also.

MRS. R.

To obviate this objection, Sir James Hall, an able champion of the Huttonian system, tried some very ingenious experiments, in which he succeeded in fusing limestone, even with a moderate heat, by subjecting it to pressure, such as he conceived it must experience at the bottom of the sea, and by that means preventing the escape of the carbonic acid gas, though Lavoisier and Saussure had failed to do it, even with intense heat, without pressure.

EDWARD.

But is there carbonic acid gas in flint also? Because, if there is not, the fusing of the limestone will not prove the fusibility of flint under the same circumstances.

MRS. R.

As there is no volatile substance in the flint, it must be confessed that it is not in the same circumstances with the limestone. With respect to the solubility of flint in water, Werner has the un-

answerable fact in his favour, that it is actually found dissolved along with lime in the water of the Geiser springs in Iceland, on the testimony of Dr. Black and of Dr. Hutton himself; and numerous facts of the same kind are to be found in most mineralogical works.

EDWARD.

But, since the disciples of Dr. Hutton try experiments to prove their system, why do the Wernerians not do the same with regard to granite and other rocks, which they should endeavour to dissolve in water, and imitate their universal solution in the original ocean?

MRS. R.

This has, indeed, been tried without success; and, when I tell you, that the flint which is formed by deposition at the Geiser springs cannot be redissolved, although it was formerly in a state of solution in the water, you will not think that the impracticability of solving it furnishes any argument against the system of Werner. Even in artificial instances, the same difficulty has occurred. A quantity of *liquor of flints*, which is made by dissolving a sort of glass, composed of

flint, potass, &c. in water, was accidentally left, by Professor Siegling, in a bottle for eight years, and, when examined, was found to have deposited crystals of quartz, which struck fire with steel. The celebrated chemist, Bergman, obtained flint crystals under similar circumstances.

EDWARD.

From these instances I would conclude, that by proper experiments, granite, hornblende-rock, and others, may, some time or other, be found easily soluble; but I might have recollected that it is a different thing to dissolve what has been formed with water from merely dissolving the materials; for, in the instance of Paris plaster, it cannot again be brought into a paste after it has been cast; and mortar, also, but more particularly Roman cement or puzzolanum, though at first made with water, cannot be dissoved by the same means.

CHRISTINA.

I think I know another instance, in which even boiling water, aided by the heat of metal, cannot dissolve a strong substance that has been formed from a solution in water. I mean the stony in-

crustation which forms on the inside of a tea-kettle.

MRS. R.

That illustration, my dear, is, perhaps, the best which has yet occurred to us; and now, having rendered this universal solution somewhat plausible, to say the least of it, we must see how the precipitation of the materials would begin, and proceed to form rocks.

EDWARD.

One thing is certain: that, if the materials of rocks were held in solution in the primitive waters, by the balance of affinities, as was mentioned a little while ago, they ought, if the circumstances remained the same, to have continued in solution for ever.

CHRISTINA.

But, Edward, you do not consider the power of God in forming rocks as well as all other things.

EDWARD.

I should be sorry indeed to be forgetful of the reverence and duty I owe to our great Creator; but we are not, as I suppose, now talking about

the power of God in creating the world, so much as about the means and agents which he employed to do it.

MRS. R.

Right, my dear: we are not, as Dr. Paley well remarks, to be precluded from examining the structure of the eye, because God, instead of giving us the sense of sight at once, has given us the very extraordinary and complicated apparatus which produces vision; for God always, as far as we can perceive, acts more by means and agents than by immediate power, and in the same way he may be conceived to have formed the world; but all these things we shall examine more in detail when we come to the Mosaic Geology, as explained by Mr. Penn; and, in the meantime, we must see how Werner explains his system of precipitations.

EDWARD.

It occurs to me, that, though the substances in the solution were balanced by reciprocal affinities, they might, at least near the surface, be so acted on by external circumstances, as would lead to the commencement of the precipitation.

MRS. R.

That is exactly the problem to be solved; for, if the balance of affinities was once deranged, the precipitation, perhaps, would proceed from that cause alone.

EDWARD.

I would suggest, then, that this might be effected by the variations of temperature to which we may suppose the earth no less subject in the primitive ages than at present.

CHRISTINA.

When I have had any lime-water standing, I have observed it sometimes become covered with a thin hard crust, explained in the books of chemistry to be carbonate of lime, formed from the carbonic acid gas of the atmosphere: now, in the original solution, lime must have also been present, in order to form the limestone and chalk-rocks. Why, then, may not the carbonic acid gas have begun the precipitation, in the way in which it acts on lime-water?

MRS. R.

Well done, Christina! you bid fair to be an

excellent Geologist; and I have much pleasure in adding to your illustration some curious circumstances respecting the formation of rocks in a similar way, within the records of authentic history.

EDWARD.

Ah! that will, indeed, bring the system to the test.

MRS. R.

I shall first, then, mention a fact in support of Edward's account of the variation of temperature. The Geiser springs of Iceland, formerly alluded to, are of a very high temperature, almost, indeed, boiling; and, as long as they retain their heat, the flint and limestone contained in them are not precipitated; but, when the water is exposed to the air till it loses its heat, it then lets fall its lime and flint, and forms incrustations of these in its course from the fountain.

CHRISTINA.

I wish you would just give my little bit of lime-water crust as good a support.

MRS. R.

I can promise you it will be still better, so far,

at least, as extent goes. We are informed, for example, by Donatus, that the water, having been interrupted in the subterranean passages of the Claudian aqueduct, at Rome, and soaking into the bibulous earth, eventually formed an extensive quarry of calcareous stone. A more extraordinary fact, which occurred in the reign of Augustus, is found related by Mercatus. At the cataract near the junction of the Velino and Neva, in Italy, so much stony matter was deposited as endangered the country of the Reatines, by obstructing the course of the river. The Roman senate despatched Marcus Curius to turn its course through the territories of the Interamnates, which induced them to complain in turn, they being afraid that this petrifying stream might turn their lands into barren rocks. But, as the Reatines were supported in their defence by the eloquence of Cicero, the Interamnates had to submit. Similar complaints were preferred by the several parties even in later times, while the deposition has now taken place to a great extent, and has often changed the bed of the river. There are authentic accounts of similar processes carried on in our own country, almost under the eye of intelligent observers of nature. Dr. Dob-

son informs us, that within the memory of persons living at Matlock, in 1774, the waters of the calcareous springs were not applied to any particular purpose, either of bathing or drinking, but ran at random down a declivity of about one hundred yards. In their course, they formed large petrified masses, intermingled with moss, nuts, leaves, acorns, pieces of wood, and trunks of trees, incrustated with calcareous matter. These substances had formed, in 1774, a bed, or, as Geologists call it, a *stratum*, five hundred yards long, one hundred yards broad, and three or four yards deep. This stone is so durable, Mr. Parkinson tells us, that almost all the houses in the neighbourhood of Matlock are built from the calcareous quarries, the materials obtained from which have been formed in the manner now mentioned. Similar phenomena have been observed all over the world, and are easily accounted for on the Wernerian system; for the original solution could continue no longer than the circumstances in which it was formed remained the same: when, by exposure to the atmosphere, the water of the solution would be exhaled, or any other volatile matters would escape, it is not difficult to perceive that a deposition must begin.

EDWARD.

These proofs appear to be irresistible, with respect to the deposition of limestone from these modern waters; but the original ocean was under very different circumstances, for, instead of containing one or two substances, like the waters of Geiser or Matlock, they contained, as it should appear, a great many substances.

MRS. R.

True: but the principles will apply as well to a solution of twenty substances as of one; and now, I think, I have given you enough for one lesson. To-morrow we shall enter on the interesting subject of the causes of the inequalities on the surface of the earth, and the formation of mountains and valleys.

CONVERSATION FIFTH.

EFFECTS OF THE EXPANSIONS ARISING FROM A CENTRAL FIRE.

MRS. R.

Now, Christina, you may prepare to hear the origin of all the romantic and beautiful scenery which you so fondly admire.

CHRISTINA.

That I shall most gladly do, if you can promise that it will not diminish my future pleasures, and draw off my attention from the picturesque effect of rocks, woods, and waters, to what have been expressively called dry facts.

EDWARD.

Well, sister, I must say that remark is very singular from you, particularly after you were

only the other day admiring the beautiful lines of Akenside on this very point:—

————————" Celestial truth,
Her awful light discloses, to effulge
A more majestic pomp on beauty's frame!
For man loves knowledge, and the beams of truth
More welcome touch his understanding eye,
Than all the blandishments of sound, his ear;
Than all of taste his tongue. Nor ever yet
The melting rainbow's vernal tinctured hues
To me have shone so pleasingly, as when first
The hand of science pointed out the path
In which the sunbeams, gleaming from the west,
Fall on the wat'ry cloud, whose darksome veil
Involves the orient; and that trickling shower,
Piercing through ev'ry crystalline convex
Of clustering dewdrops, to their flight opposed,
Recoil, at length, where concave all behind
Th' internal surface of each glassy orb
Repels their forward passage into air;
That thence direct they seek the radiant goal
From which their course began; and, as they strike
In different lines the gazer's obvious eye,
Assume a different lustre through the brede
Of colours, changing from the splendid rose
To the pale violet's dejected hue."*

MRS. R.

You deserve credit, Edward, both for your apt

* Pleasures of Imagination, book 2.

answer to your sister's objection, and for the accuracy of your memory in quoting the lines. No: so far from diminishing the pleasures of taste, knowledge should, and does, increase them.

CHRISTINA.

I shall certainly welcome every thing which has such a tendency; but I fear the difficulty of understanding the causes that operated in producing picturesque scenery will prevent me, in some measure, from deriving the promised advantages.

MRS. R.

And yet I have to tell you of no other causes than those I have formerly mentioned. Dr. Hutton, for example, says, that the inequalities on the earth's surface,—the hills, valleys, plains, and beds of lakes and rivers, have in the first instance been caused by the upbearing of the materials collected and consolidated at the bottom of the sea by means of heat, as I formerly explained to you; and, in the second place, the rough and unequal surface of the earth, thus formed, has been smoothed and modified by earthquakes, avalanches, and volcanos, but more particularly by the action of rains, frosts, and running waters.

EDWARD.

This action of the central fire on rocks, and even its very existence, we formerly agreed upon, if I recollect aright, not to be proved.

MRS. R.

Yes, my dear; but we shall understand the subject better, perhaps, if we concede to the Huttonians the existence of their central fire, and confine ourselves for the present to inquiring into the probability of its having elevated the mountains from the bottom of the sea.

EDWARD.

It will not, I conceive, be an easy task to prove this upbearing of the rocks by the central fire, even granting its existence, and I am anxious to hear the reasons brought forward by Dr. Hutton.

MRS. R.

He takes two modes of supporting this part of his system:—

One, by endeavouring to establish the fact, that there has been a vast convulsion of nature, by which rocks that have evidently been formed in a horizontal position, are now found either

standing upright, or nearly so, or, to express the same thing geologically,—vertical or at high angles of inclination.

Another, by trying to prove that such appearances of rocks, rugged and broken, cannot be explained by either crystallization or subsidence, and, therefore, must have been occasioned by the expansion of heat.

EDWARD.

One of these propositions, I think, might be easily proved. I mean the assertion, that there has, in former ages, been a vast convulsion of nature; for every rock almost that we see demonstrates this, as clearly as the existence of beds of lava demonstrates the previous eruptions of Ætna and Vesuvius.

MRS. R.

The remaining part of this first proposition, respecting the upright, or nearly upright, situation of many rocks, is also easily established. In the Alps, for example, over which, with the assistance of Saussure, you may travel geologically by the parlour fireside, there is a large proportion of rocks stratified vertically; and the same observation has been made in almost all the Alpine mountains, which have been examined in every

quarter of the globe, as in the Andes, the Pyrenees, and the Altean mountains, on the borders of Russia.

EDWARD.

I remember you formerly told us, when speaking of the order of rocks, that granite is generally perpendicular.

MRS. R.

Granite, however, is not the only species of rock that is found in this position, for all the rocks of more ancient formation, as the Geologists say, tend towards this; and even the newer rocks, such as the conglomerates or breccias, have been found vertical in Alpine countries, and under circumstances which scarcely admit of a doubt that they must have been *first formed* in a horizontal position; and, if so, the fair inference is, that they have been raised by some powerful agent to their present elevation.

EDWARD.

But, then, there must also be some notice taken of the rocks which are found horizontal or approaching to it; and the objection formerly made will recur, namely, that the expansion has operated very partially; otherwise, why has gra-

nite become vertical, while sandstone and gypsum, you told us two days ago, remain horizontal?

MRS. R.

I pretend not, indeed, to maintain or defend Dr. Hutton upon this point, for I think we may draw from it the very absurd conclusion, that the heat raised the Alpine rocks highest, because they were composed of the heaviest and most durable substances, which you will perceive is analogous to another Huttonian supposition formerly mentioned: namely, that the expansive power of heat remains quiet during the accumulation of rocks of incalculable weight and thickness at the bottom of the ocean, and only awakes from its lethargy when the mass has been completed.

EDWARD.

But might it not be, that the expansion of heat which elevated our present continents and islands, was exerted at different periods, and was more violent in its operations when it raised the more ancient rocks, than when the secondary were elevated?

MRS. R.

Then we must either infer its capricious expan-

sions, or that it had diminished in power: the first of which inferences corresponds with great exactness to Dr. Hutton's theory; but the second, if just, would, in one view of the subject, disappoint all hopes of the emergence of *another* continent from the bosom of the waves, and consequently refers to the present order of things as the last link of that illimitable series of worlds which Dr. Hutton's theory teaches us to expect.

EDWARD.

I think I could explain, in a probable manner, how the heat would diminish in power.

MRS. R.

It will give me great pleasure to hear your explanation; but I fear you will become too hard for me, if you go on as you have begun, with your objections and explanations.

EDWARD.

The explanation I would suggest is, that when the expansive force operated so violently as to elevate the horizontal rocks to a vertical or upright position, the crust of the globe, lying over the supposed central fire or region of heat, would

be rent asunder, and chasms would be formed contiguous to the rocks now forced up, which chasms would be proportional in width to the height of the rocks so elevated. As such chasms, then, must, in some of the Alpine countries, have been many thousand feet in width, and corresponding in length with the Cordilleras and other Alpine chasms, the escape of heat to a vast extent must have taken place.

MRS. R.

Very well: this is, indeed, a better explanation than I have heard any of the Huttonians give of the circumstance, and, in the hands of a good advocate, it might be turned to advantage in obviating the objection drawn from the inferred rest and quiescence of the expansive power during the accumulation of materials at the bottom of the sea; for the quantity of heat thus escaping, could not soon be replaced from the generating fountain at the centre,—perhaps not till there might be formed a sufficient thickness of rock to form the basis of another continent.

EDWARD.

Yes: but, while this serves to obviate one ob-

jection in some degree, another, no less formidable, suggests itself to me. If I have understood the theory aright, it explains only the upbearing of rocks generally; but it appears from what you have told us, that it is only the more ancient rocks which are found vertical, while the newer rocks, sandstone, gypsum, and shale, are horizontal, or nearly so. The expansion, then, must have acted capriciously, independent of any quiescence from the escape of heat through chasms; otherwise, we should have great irregularity in the elevation of rocks, and as readily find horizontal granite as vertical sandstone and shale.

CHRISTINA.

If I may venture to ask, I should like to ascertain whether there are, in reality, any such great and tremendous chasms as Edward has supposed. I know there are great craters in volcanic mountains, formed by the melting down of the rocks by the subterranean fires; but I have never heard of any chasms such as he has been talking of.

MRS. R.

But it does not follow, my dear, though such chasms were formed, and heat escaped from

them, that they would always remain open. Supposing such a rent to have taken place, there would be thrown up on each side a vast mass of rocky materials, at elevations proportioned to the force which upheaved them. Yet, as soon as a sufficient quantity of heat escaped to leave the walls of a chasm unsupported by its expansion, they would infallibly either collapse and resume their original position, or sink till they met with no resistance.

EDWARD.

This latter effect, however, would still leave a great breach of surface somewhere.

MRS. R.

And, unfortunately for the theory of Dr. Hutton, the appearances of nature give no colour to the supposition. It is at variance, indeed, with all the phenomena exhibited in mountain ranges. In all the Alpine chains of mountains hitherto examined, there is observable a central ridge, from which branch off innumerable lateral ridges, commonly taking the direction of the central one.

EDWARD.

That is a very interesting fact, and it would be

no less interesting to ascertain whether the central and the lateral ridges of a mountain-chain are the same or different in structure, and in the species of rocks that compose them.

MRS. R.

So far, my dear, this is ascertained,—that the central ridge is generally, if not always, of very different materials and structure from the lateral ridges; though Dr. Hutton's theory would lead us to expect them to be uniformly similar: for, if Edward's supposed chasms were formed between the central and lateral ridges, they should be exactly of the same materials, having been merely disjoined by violence; and the only supposable difference ought to be in the position of their rocks, formerly horizontal, which would of course fall down, again close up the chasm, and imprison the heat; while, in the central ridge, as the rocks may have been previously vertical, the chasm would close vertically; but still there would be left appearances to indicate such a convulsion, —and nothing of this kind, so far as I know, has ever been discovered in mountains, though their magnitude would almost preclude the supposition of concealment, if they did really exist.

EDWARD.

I must, then, I fear, give up this supposition of chasms; but another view of the matter suggests itself to me, which I imagine will not be more favourable to Dr. Hutton.

CHRISTINA.

But, Edward, if you go on objecting and objecting in this manner, we shall never get on.

MRS. R.

On the contrary, my dear, it is the very thing that will make you understand Geology more thoroughly, and fix it more deeply in your memory: so, Edward, you cannot do better than give us this threatened objection.

EDWARD.

I would suggest, then, that no expansion, short of explosion, could well have elevated, to their present position, the great Alpine rocks of vertical granite; for, as soon as the crust of rocks, supposed, by Dr. Hutton, to lie at the bottom of the sea, over the region of central heat, should be burst by a violent expansion, the immediate escape of a vast quantity of heat would weaken or

destroy its elevating action, and, instead of rising, the rocks would actually sink; an event which would happen (if no explosion took place) long before the rocks could be elevated to a vertical position.

MRS. R.

Very ingenious, I must confess; but, if an explosion did take place, the positions of rocks would be much more irregular than we now find them to be, and the vertical position would not be a characteristic of one class of strata more than another. There is one fact which would strongly support the supposition of explosion: I mean the occurrence of large blocks of granite and other rocks, detached and far distant from their original beds, from which they appear to have been forcibly rent and carried, by some powerful agent, to their present position. Explosion, however, is inconsistent with so many other appearances, that we must, I fear, give it up, and explain the occurrence of the detached blocks in some more plausible manner.

EDWARD.

Does Dr. Hutton explain how it happens that there are, as you have told us, extensive tracks of *Horizontal Rocks?* For surely these ought, in

unison with his supposition, to have been broken up, elevated, and set on edge, at the same time as the vertical rocks.

MRS. R.

I am not aware that the Huttonians have explained this; but there is one part of their theory which might be alleged in support of it. As they cannot suppose that horizontal rocks of so great extent as are often found in nature, could possibly be elevated in the manner which they allege, without any indications of shattering or fracture being discoverable, and as no such extensive indications have been, nor probably ever will be found, if these rocks, as they say, were formed at the bottom of the sea, they must have remained there submerged for ever, had not the waters, by some means or other, subsided, or been drawn off; and, perhaps, they may attempt to account for this on the supposition, that the diameter of the globe will be enlarged at each successive elevation of rocks from the bosom of the sea, and consequently the land will increase upon the water.

EDWARD.

This last inference, I think, would require very strong proof to make me believe it.

MRS. R.

I do not require you by any means to believe it, as it certainly is not supported by Geological facts; but there is another view of the elevation of rocks given by the Huttonians, that is worthy of your attention. We have all along been considering that the rocks supposed to have been raised, were of a considerable degree of hardness before, as well as at the time of their elevation; but Dr. Hutton conceives that no inconsiderable portion of them were soft enough to be bent without breaking, and that some of them were thrown up in a fluid state, like the lava of volcanos.

EDWARD.

Ah! that alters the case very much; but yet, if the materials of the rocks were merely in a soft flexible state when they began to be expanded by heat, it is evident that, unless they were also elastic, they could not have been blown up into mountains (if such an expression be allowable), by the action of heat from below, without having been *broken through*.

MRS. R.

Your inference, I think, is quite fair; and it will also follow, that, if they were of the consistence of

melted lava, there would be formed, by expansion, huge vesicular mountains of the shape of a glass-house or of a sugar-loaf, having, in most cases, an opening at the top, like the crater of a volcano, with the walls gradually decreasing in thickness from the base to the summit.

CHRISTINA.

This is a very fine fancy, if it correspond with appearances; and, I think, most mountains which I have seen do.

MRS. R.

The granite mountains of Alpine regions certainly do not accord with the *fancy*, as you have happily called it; for their distinguishing character is sharp angular peaks, in Switzerland expressively called *Needles*, and this is at total variance with the fancy. Even basaltic mountains, although they generally stand apart from other mountains, and are of a conical form, show nothing on their summits analogous to the volcanic craters, but are rather, on the contrary, rounded at top, like the hillocks of alluvial formation often met with in Switzerland. For example,—the Priory of Chamouni is built upon the materials

washed down from Mount Bréven,* which, on the right and left, have taken the form of a *cone,* a common occurrence in valleys surrounded by high mountains.

EDWARD.

On the supposition that the materials of rocks were in a state still nearer to hardness, it is plain that expansion could not operate so easily in raising them to considerable heights; and, as rocks would not, I imagine, in such a state, possess much elasticity, they must either have been shattered and broken, or raised in a bent form to small elevations.

MRS. R.

It lends some support to this notion, that rocks are occasionally found in a bent form, as in the gneiss rocks of the Islands of Scotland, and near Liogny, in Switzerland, where the rocks, horizontal at the summit, are bent almost at right angles, after which they descend perpendicularly. These occurrences, however, are not only rare, but the

---

*. Saussure, Voyages dans les Alpes, s. 640.

bending is for the most part in a contrary direction to that which would have arisen by expansion from below.

EDWARD.

That must, consequently, be fatal to the whole supposition. But, supposing the materials of the rocks to have been in a very fluid state, the appearances which ought to follow would be exactly what are observed in volcanic eruptions of melted lava.

MRS. R.

Right: and this view of the subject is well calculated to explain the appearances of detached mountains of basalt and sienite; but it fails entirely to account for the formation of Alpine ridges, and especially of the Swiss Needles, or peak-shaped mountains of granite, a good instance of which occurs in the mountain ridge of the Island of Arran, in the Firth of Clyde.

EDWARD.

On all these points, I think, respecting the upheaving of rocks by the expansion of heat, the facts agree but indifferently with the theory, and often oppose it; and, if Dr. Hutton's second series of causes be not more plausible, I must de-

cline the honour of becoming one of his disciples.

MRS. R.

You will do well, at all events, to weigh his arguments thoroughly before you either adopt or reject them. As for you, Christina, I am sure the subject has been romantic enough for your greatest stretch of fancy.

CHRISTINA.

It has, indeed, quite overpowered my feeble conceptions, with grand convulsions and unfathomable chasms sending forth subterranean fires, and strewing the wide earth with rocks and mountain ridges.

MRS. R.

You will be more delighted, I imagine, with the next subject: I mean Dr. Hutton's account of the effect produced by the weather and by water on the surface of the land.

CHRISTINA.

That will, indeed, be interesting, and must lead, I anticipate, to some fine descriptions of storms and torrents. I must first point my pencil, I suppose, to take sketches.

MRS. R.

Not just now, my dear, as I have a particular engagement. But I shall be ready to assist you to-morrow, and, in the meantime, you may amuse yourself by sketching one of Edward's chasms, or a mountain range, with its grand central chain, lateral ridges, and intermediate valleys.

CONVERSATION SIXTH.

FORMATION OF RAVINES, VALLEYS, AND RIVER COURSES.

MRS. R.

Let us now suppose the continents and islands raised above the waters, by whatever means that might be done,—for, on this point, we received no satisfactory information from Dr. Hutton,—we must consider what causes might operate to modify or change their appearance.

EDWARD.

Yesterday, you hinted something about the operation of the weather upon rocks; but I cannot conceive that this would have much other influence than, perhaps, changing their colour.

CHRISTINA.

Yes; in the same way as an old ruined castle

is gray* and gloomy, while a modern building of the same stone looks fresh and trim.

MRS. R.

Dr. Hutton remarks, that, from the instant the continents were raised above the water, the process which was destined to destroy them commenced. Rain would be poured from the clouds upon the earth, running down from the mountains in a thousand runnels, which, uniting in valleys, would form streams, brooks, rivers, and occasionally lakes. When a vast sheet of water was precipitated over a rock and formed a cataract, pieces of the rock would be detached by the violence of its action, and, several such pieces being rolled and rubbed upon one another by the eddies and currents, their angles would disappear, and they would assume a form considerably rounded.

CHRISTINA.

I can understand this much better than the

* "Les murs de l'edifice avaient reçu du temps cette couleur de feuilles séchées, que le voyageur observe encore aujourd'hui dans les ruines de Rome et d'Athens."—*Chateaubriand, Martyrs*, 1.

chasms and convulsions which we were discussing yesterday.

MRS. R.

The process does not terminate here: the first fragments, thus broken off by the force of the water, would also again occasion, sometimes by the same means, the detachment of others; and the incessant friction of the stream itself would hollow out its channel to a depth which, in the lapse of ages, could not well be calculated.

EDWARD.

This, however, cannot always be the case; for I recollect reading, in Captain Beaufort's account of the coast of Karamania, that he saw a river which had its bed raised high above the plain through which it flowed.

MRS. R.

I recollect the fact, but that river is loaded with limestone, which it deposited in its course, and, consequently, is an exception rather than a rule to go by. Dr. Hutton proceeds to remark, that the finer particles rubbed off from rocks by the current of a river, would be slowly carried forward by the stream to its termination in the sea,

and would either be gradually spread over the bottom, or be thrown upon its shores, as happens under favourable circumstances even on the banks of rivers.

EDWARD.

Ah! this will make me brush up my classics a little; for I remember that Herodotus, the father of historians, says, that the greater part of Lower Egypt is the "gift of the river;" and Cicero says, that both the Nile and the Euphrates produce new fields in a few years.*

MRS. R.

This is exactly in point; but you will have no less use for modern than ancient learning here. The French traveller, Denon, if you remember, describes the actual process of the formation of the Delta.

CHRISTINA.

Here is Denon's book: shall I look for the passage?

MRS. R.

Yes, my dear; and be so good as read it to us.

---

* Cicero, De Naturâ Deorum, ii. 52.

CHRISTINA.

He says, a north wind blowing against the mouth of the Nile, about August, the contending waters of the river and the sea thus throw up a bank or island of sand, which has the effect of dividing the river into two branches. The eddy formed by this island throws back on the beach the sand that has been brought down by the river; and thus, at length, one of the lately formed branches is blocked up, the island becomes entirely connected with the main land, and the remaining branch repeats the process, a new island being formed at its mouth, and so on. The newly-formed land first produces three or four kinds of sea-weeds, round which the sand throws itself in heaps; the subsequent decay of this weed furnishes a manure which favours the vegetation of weeds; and these weeds give a greater elevation and a greater solidity to the soil: the date-tree now appears, and by its shade prevents the sudden evaporation of the moisture; till at length, the Delta having by degrees been more and more extended, forests and palm-trees, and even towns, built a few centuries ago, are seen at a league's distance from the shore, on spots which were once covered by the sea.

MRS. R.

Humboldt says, that a great part of the sand and other materials of rocks washed down from the land by the Mississippi and Rio del Norte, into the Carribbean Sea, are thrown up again by the Gulf-stream along the coast of America, forming great sand-banks; and similar accounts are given by Major Rennell, of the materials washed down by the Ganges, and by Mr. Barrow, of those washed down by the great Yellow River, or Hoanho, of China. It would be easy to give you numerous instances of this.

EDWARD.

I should like to know all the instances which have been ascertained, that I might compare them together.

MRS. R.

That would, indeed, be very proper, and I shall take care to give you a note of them, with a reference to the works where they are best described. What we have been considering, however, is only the effects of water in quiet and gentle rivers; the case is much stronger when we take the instance of a mountain torrent.

CHRISTINA.

And more picturesque, I will answer for it.

MRS. R.

Of that you shall judge by the description of De Luc, who tells us, that a single momentary flow of this kind, in the Swiss Alps, transports such a quantity of what is vulgarly called *sludge*, but by Geologists, *Debris*, as at once to change the appèarance of a considerable extent of ground, carrying away whole forests at " one fell swoop."

CHRISTINA.

Such a scene must be awfully grand; but I should be too much alarmed to enjoy it.

MRS. R.

Saussure gives us a more accurate notion of these Alpine torrents, by describing their origin, which, he says, arise from basins of water formed in the slate-rocks, that are soft and easily crumbled down, forming a bank which confines the water. This goes on accumulating from rains and the melting of snows, till it reaches a certain height,

when all at once some weak part of the bank gives way, and the waters, bursting over their prison-walls, descend with a terrible impetuosity, in the state of liquid mud, mixed with fragments of slate and other rocks. The force of such a torrent, he says, is indescribable: it tears down rocks, overthrows buildings, roots up the largest trees, and desolates the fields, by excavating deep ravines and covering the surface to a considerable extent and depth with sludge, gravel, and fragments of rocks.

EDWARD.

Such a powerful agent as this would account as well, I think, for the distant and detached blocks we were talking of yesterday, as the untenable supposition of an explosion from below.

MRS. R.

So thought the celebrated Saussure, whose description I have just given you. He imagined that, in some former age, a much more tremendous torrent, or *Debacle*, as he calls it, than any in modern times, occurred, and, by the grand rush of its waters, transported from the Alps the great blocks of granite now found so abundantly scat-

F 5

tered over the limestone country around Geneva. He mentions one striking instance, which occurred so late as July, 1751, after a winter remarkable for an unusual fall of snow, when a great part of a mountain, having three lakes at its summit, gave way, and fell with a tremendous crush, at Servoz, near the valley of Chamouni. The masses of rocks which were then hurled down, amounted, collectively, to three millions of cubic feet.

EDWARD.

These, however, are at present, I presume, rather singular occurrences; but the ordinary torrents of a mountain district ought to operate with considerable effect in destroying the rocks in their course.

MRS. R.

Certainly; and Dr. Hutton goes so far as to affirm, that those torrents, and the rivers formed by the union of several of them, are the sole agents which have hollowed out all the channels, ravines, and valleys, through which they run.

EDWARD.

That assertion seems to take in rather a wide view. The idea has sometimes occurred dimly

and indistinctly to myself, while fishing along the banks of a hill-stream; but, when I looked at the little current as it gurgled along from pool to pool, and compared it with the huge walls of massy rock, or the bank of solid turf sloping away for two or three hundred feet above me, I dismissed the rising fancy from my mind as improbable.

MRS. R.

But, had you known the history of the Alpine torrents, you might, perhaps, have been induced to think the improbability not so great; as the first excavation may have been thus begun, and the daily current of the common stream, however tiny it might be, could, perhaps, continue or finish the hollowing of the valley. It is worth remarking, also, that unless a person has lived in a mountainous country, no idea can be formed of the sudden swell of the most inconsiderable streams.

EDWARD.

Oh! I know something of that; for one day, during a fishing excursion, the stream began to swell all on a sudden, and, though it was previously too clear for my sport, it became all at once dark and muddy, and I then perceived, from

the gloominess of the clouds, that it rained heavily higher up among the mountains.

MRS. R.

This accords exactly with what occurred to Professor Kidd, when returning from a mine near Tyndrum, in the Scottish Highlands: he found his retreat cut off by a rapid river, some yards in breath, in a part where, in his way to the mine, a few hours before, he had not observed the track of even the least water-course, much less of a stream.

EDWARD.

But this would prove, at least, if this was the regular course of even an occasional river, that running water has not much effect in hollowing out valleys.

MRS. R.

The professor was disposed to draw this very inference; but it would be wrong, I think, to rest on an individual instance of this kind, when so many facts are in favour of Dr. Hutton's notion. Saussure, also, who is one of the best authorities, is in some measure of the same opinion; and he tells us, that, in looking from an eminence on the group of hills called Mont-Ferrat, in the vicinity of

Turin, it may easily be perceived that the innumerable valleys which furrow those hills in every imaginable direction, are the work of streams arising from rain; for they have all a considerable degree of inclination, are narrow towards their extremities, and wider as they approach the plain.

EDWARD.

There can be no doubt, also, I think, that the action of running water on rocks will be in proportion to the softness or hardness of the materials with which it meets.

MRS. R.

You are quite right, my dear; and the effects are very generally observed all over the world. Pallas remarks, that the valleys in the Altain chain of mountains which separate Russia from China, have been evidently formed by numerous rivulets and torrents, occasioned continually either by rain or the melting of snow; and the mountains, by the same agents, have been reduced in height and magnitude. These, however, are only the opinions of Pallas, which, however probable, cannot be proved.

EDWARD.

One excellent mode of proof occurs to me: I mean, if any very precise passage in an ancient author, describing a mountain, ravine, or river-course, were compared with its present state.

MRS. R.

With the assistance of Saussure, I can gratify you with one striking instance, which will please you the more, that it illustrates your remark respecting the comparative hardness of rocks. You recollect, perhaps, a passage in your favourite author, Cæsar, where he describes a defile in Switzerland, as a narrow and difficult road, between Mount Jura and the Rhone, through which a single car could scarcely pass, while a very high mountain hung over it. This is as precise a passage as you could wish; and Saussure tells us, it does not seem that the river has made the least alteration in the defile for two thousand years. Saussure, therefore, thinks that, though the pass has been hollowed out by the action of water, it could not have been by the ordinary flow of the Rhone, but by some mighty

current, which issued from the basin of the lake, when its waters were at a much higher level.

EDWARD.

This is, indeed, a beautiful instance, and alone fully recompenses me for the little attention I have lately given to Geology.

MRS. R.

I can give you another, perhaps still more interesting. When Alexander the Great arrived with his fleet at the conflux of the Hydaspes and Acesines, the rapid and troubled stream formed by the union of the two rivers, and confined by steep banks, struck his whole forces with dismay, and proved fatal to some of his largest vessels. Now, Major Rennell remarks, that more than two thousand years afterwards, in 1398, Timour found the same rapid and troubled current opposing his progress at the same place, as may be seen in Shereffedin.

EDWARD.

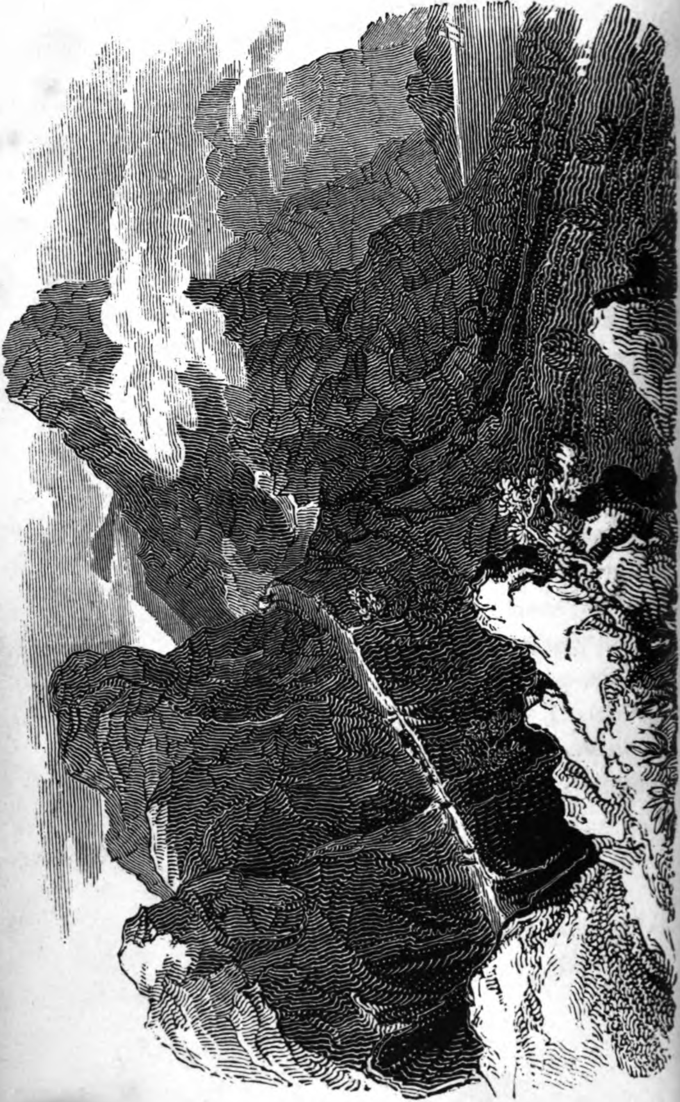
This is not quite so precise, however, as the passage from Cæsar.

MRS. R.

I recollect, when I was last in the north, being struck with an instance, on a small scale, very similar to what Saussure supposes to have been the origin of the pass of the Jura and Rhone. About a mile beyond the village of Manchline, in Ayrshire, is the romantic scenery of Howford, where the River Ayr passes between lofty walls, almost perpendicular, of reddish brown sandstone. Now, this hollow and narrow passage of the river has evidently been formed by water, as the wearing of the rocks by the current is obvious at more than a hundred feet above the level of the present channel: yet I doubt very much that it could have been scooped out by the river in its present state; and I think it much more probable that, in some early age, what is now the pretty valley of Catrine formed a deep lake, the outlet of whose waters wore a deep channel through the picturesque rocks of Howford and Barskimming.

CHRISTINA.

Your description of Howford agrees very ex-



actly, I think, with what I have just been reading of Roslin and Hawthorndean.

MRS. R.

Exactly; and I have no doubt that there was formerly a deep lake above Roslin Castle, in the valley which is at present employed as a bleach-field. A similar instance occurs near Auchenleck House, the family seat of the celebrated Boswell, the biographer of Johnson; and in England, the beautiful dales of Derbyshire have probably had a similar origin. A good instance of a similar ravine occurs at Hottentot Holland's Kloffe, at the Cape. [See the Plate.]

EDWARD.

I should imagine that it would be no very difficult matter to ascertain whether streams and rivers produced any sensible change upon their channels, or on the adjacent banks. I have often, indeed, remarked large masses of turf and gravel on the banks of rivers, undermined by the current, and falling down.

MRS. R.

Of this there are many examples recorded: the river Severn, for instance, a few miles below

Gloucester, has, within the memory of man, worn away a considerable portion of its right bank, so as to form a precipice, near Wesbury, which is called Garden Cliff, with a considerable depth of water on that side of its channel. Professor Kidd, a few years ago, remarked, that the track of a road had been abruptly cut off in consequence of the gradual undermining of the cliff.

EDWARD.

Probably, all steep cliffs on the banks of rivers were formed in a similar manner, by the undermining operation of the current, which will be most likely to attack the softest materials it meets with, and avoid those that are harder.

MRS. R.

How far the latter may hold, I am not prepared to say, but the softer materials are usually attacked and deposited on the opposite bank, by the back-current always formed in such cases, in consequence of the opposing obstacle. You will, therefore, most generally find a flat, or nearly flat, field, or a bed of gravel, opposite to a steep river-cliff. A good instance of this occurs

on the river Cherwell, between Islip and Woodstock.

EDWARD.

I have often observed such instances, but I never thougnt of the cause, which this explanation renders very probable.

CHRISTINA.

What you have told us, mother, of all this picturesque river scenery, is very fine, and I am delighted that I can understand it; but suppose you were to pass from the mountains, the hollow valleys, and the steep cliffs, to the beauties of a more level country, where the rivers glide between smooth grassy banks.

MRS. R.

In that case, the changes would be less obvious, though they would depend much upon the previous track of the river in its mountain course.

CHRISTINA.

I confess I cannot understand that; for the previous course of a river, at the distance of twenty, fifty, or a hundred miles, cannot, I think, have much, if any, influence on its current as it

passes through the green level meadows near the sea-coast.

MRS. R.

You forget, my dear, what we were saying a short time since, respecting the Nile, and other great rivers, depositing so great a quantity of sand and mud as to form large tracts of land,—some of the newly-formed islands at the mouth of the Ganges being, according to Major Rennel, as large as the Isle of Wight. Now, whence do you imagine all these materials could be derived, if not washed from the mountains and higher grounds through which the rivers run?

EDWARD.

I beg pardon for inattention; but I was thinking of what you told us a little while ago concerning the cliffs undermined by rivers, and the flat banks and meadows usually opposed to them, which, if I recollect right, are, for the most part, in the instances which I have seen, composed of sand and gravel,—the ruins, evidently, of the cliff that has been undermined. But what is more extraordinary to me, is great beds of gravel and sand where there are no rivers or streams to have swept them away from rocks or cliffs.

MRS. R.

The beds of sand, gravel, and stones, which you mention, are among the most interesting subjects of Geology, and are most satisfactorily explained by Mr. Granville Penn; but it will be better to wave his account of these till we come to his system, and consider what Dr. Hutton and others say on the subject.

EDWARD.

If they account for the gravel as plausibly as for the action of rivers, I shall be satisfied; for I cannot see how the reasoning could be improved.

MRS. R.

Mr. Penn, however, we shall find, gives a very different history of rivers; but, as to the original gravel-beds, we are referred by other Geologists to the action of the weather and the operations of the deluge.

EDWARD.

I should have some doubts of the possibility of frosts, thaws, and rains being capable of producing such beds of gravel as I have seen, even in the longest course of years.

MRS. R.

That would depend very much on the nature of the rocks, on the same principle that currents rapidly wear away some rocks, and make little impression upon others.

EDWARD.

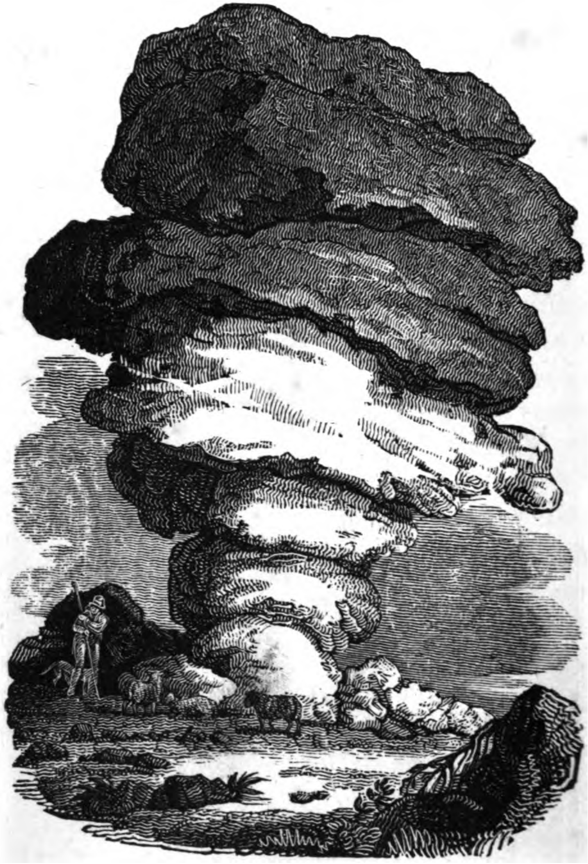
Frost, I am aware, is a powerful agent in such cases, when it meets with water, from the ice crystallizing in an angular manner, and consequently swelling out; but, without water, frost could not crumble down the least fragment of a rock.

MRS. R.

True; but how many rocks are there whose slaty, shivery, or jointed structure, allows water to penetrate; and then comes the frost, crystallizes the water into a strong wedge of ice, which loosens and rends them asunder, and strews them at the bottom of cliffs, slopes, and mountains.

CHRISTINA.

Ah! I understand now, how the Alpine travellers, when passing under such cliffs, are forbid



to fire a pistol, or even to speak aloud, as the least agitation of the air might dissever the fragments loosened by the frost, and bring them toppling down on their heads.

MRS. R.

In Cornwall, and some other places, this action of the weather has, in several instances, worn away part of the jointings of large blocks of granite, which are, in consequence, left resting on a kind of central pivot, and are, from that circumstance, easily moved, notwithstanding their immense weight and bulk. These are called tors, or rocking-stones, and were the objects of Druid superstition; among these is the celebrated pile of rocks called the Cheese Wring, a drawing of which is in my portfolio.* [See the Plate.]

* The Cheese Wring is a natural pile or combination of rude rocks, rising to the height of thirty-two feet, and standing near the top of a hill. The stones are placed one above another; and from the shape of some of them resembling a large cheese the group obtained its name. It consists of eight stones; the uppermost was formerly a logan, or rocking-stone; but part of it having been broken off, the equipoise was destroyed, and it is now immovable: on the top were two hollows, or basins, one of which is yet whole. The great weight of the upper part, and the slender bearing between the third and fourth stones, have excited much admiration how such an ill-constructed pile could resist the storms of such an exposed situation for so many ages. On the same hill are several other small groups, all of granite, and one of the

EDWARD.

Still I am not satisfied as to the extent of this action, for I have seen some gravel-beds of miles in extent and several yards in depth.

MRS. R.

The bottom of almost every hill and mountain where the rocks are permeable to water and frost, would convince you of this. In this country we have striking examples of this: at Mam Tor, in Derbyshire, where an immense hill of broken rock is piled up at the bottom of a precipice; at Skiddaw, in Cumberland, a similar phenomenon may be seen; and at Arthur's Seat and Salisbury Craigs, near Edinburgh, where the dissevered fragments of rock are of all sizes, from that of small gravel to that of a block of many tons' weight. De Luc gives a still more striking in-

---

stones of the enormous measurement of eleven yards in length, and nine in breadth; the thickness, on a medium, little more than two feet. The hill is of a conical shape, and the diameter of the summit about one hundred yards. Round the top is an immense number of small stones, seemingly ranged by art, and forming a rampart or wall. Within the circle are many large masses of rocks, with excavations on the tops of some of them, called *rock basins*; these are nearly regular and uniform, and generally two together, with a spout or channel between them."

stance: the parts of Mont Blanc, he says, which are not covered with perpetual snow, wear away by the action of the weather, and the separated fragments, falling on the glaciers below, descend with them, and accumulate at their edges in large heaps, called *Moraines.* One of these, on the south-east of Mont Blanc, which is very extensive, consists of masses of granite, serpentine, quartz of all colours, mica-slate, and other rocks.

EDWARD.

Had I been aware of such interesting facts as these, I should not have whispered a doubt respecting the effects of the weather.

CHRISTINA.

It would form a good subject for a sketch, to draw Mont Blanc or Skiddaw in the distance, and exhibit, on the foreground, the fields at the base strewed with the weathered fragments of rock ruins.

EDWARD.

All this, however, does not explain to my satisfaction the origin of gravel; for even on the tops of hills, where there is not and could not be running water, the pieces are rounded in the very

same way as those are which have been worn round and smooth by the current of a stream.

MRS. R.

There can be no doubt, my dear, that a current of water rounds and smooths the fragments of rocks and stones which it meets with in its course, a beautiful instance of which fell under my own observation, above Cumnock, in Ayrshire, where Glenmore water is nearly stopped in its brawling course by large square and angular blocks of the rocks through which it passes. These blocks are much too large to be smoothed or rounded by the stream; but a little below, near Bello Mill, the stream having passed the great square blocks, the stones are small, smooth, and rounded. But, though this is the effect of water, frost may in the same way crumble off the angles of small stones and gravel, and round them as well as water.

EDWARD.

I did not think of that; but (if I may say so) you are forgetting the deluge, which you mentioned as one of the agents in producing gravel-beds.

MRS. R.

The immense stream of the flood of Noah would undoubtedly tend both to round the gravel and stones scattered on the earth's surface, and would also collect them in the extensive beds where they are now found; but one fact of a very singular kind is opposed to this supposition. In many, if not in all the great gravel-beds, the bones and other remains of the animals of a former world are found in great abundance; but no human bones have hitherto been discovered in such situations. The inference is, therefore, that the gravel-beds were formed before the existence of the human race.*

EDWARD.

That is a very singular fact, indeed, and is well worthy of examination; but it is only a negative, not a positive proof.

MRS. R.

You are right: but the subject will afterwards

* See Conversation XIV.

come under our notice in a different point of view. I have already told you of the beds of stones and gravel formed by rivers; but you must not suppose that all rivers form beds of stones and gravel. In a flat marshy country, and at a distance from rocks, they can only form banks of sand, mud, and soil, as may be seen is the case with the Thames, below London; the Nith, below Dumfries; and the Clyde, below Rutherglen. Dr. Barrow makes the same remark respecting the Hoanho, or Yellow River, below Pekin, where neither a stone nor a pebble of any magnitude occurs for many miles, the whole tract being fine sand to a great depth, evidently deposited by the river; and this is not to be wondered at, when he found by experiment that the mud daily carried down by the river exceeded two millions of solid feet in an hour. Major Rennell says, that from Calcutta to Lucknow, a distance of six hundred and fifty miles, is one vast plain of sand and mud; and no substance so coarse as gravel is to be found here, in the track of the Ganges, within four hundred miles of the sea.

EDWARD.

All the soil and mould, then, it would appear,

on which plants grow, is at first produced by the weather, and by streams of water crumbling down the surfaces of rocks and rubbing off the corners of stones and gravel.

CHRISTINA.

This is, indeed, an interesting view of the subject. I find I shall be much pleased with our geological lessons.

MRS. R.

Edward, however, is not altogether correct in his notions about soil; for, though at first it is certainly composed of what I may call a sort of paste, formed by crumbled rocks and the moisture of rains and dews, yet this would never form the black rich mould of gardens.

CHRISTINA.

But this is precisely what I should like to know about.

MRS. R.

It is not, perhaps, in strict language, a part of Geology; but, as it comes in our way, it may be interesting to consider it: and, by way of preface, I may ask you how you suppose a little tiny patch

of moss finds soil to nourish it on the top of a brick wall?

CHRISTINA.

Indeed, I cannot conjecture, unless the moss can grow on the naked bricks.

MRS. R.

No: that is not the fact: for you will always find it rooted in fine black mould, and it is the origin of this mould which we want to discover.

EDWARD.

It occurs to me, that this may be partly produced, at first, by the action of the weather.

MRS. R.

But then, my dear, it would be brick-red, and not black, as we find it is. I confess I cannot go to the very origin of the process, but the first discoverable trace of it on a new brick or stone wall is a green silky-looking substance, having somewhat the appearance of green paint. When this is examined by the microscope, it is found to consist of very minute leaf-buds of some of the

mosses;* but whence the seeds of these come, nobody can tell. As there is in the first instance scarcely any support for these mosses, minute though they be, they never advance farther than the bud, but die with the next dry weather which occurs, leaving their remains to rot and form the first particles of vegetable soil, or, as it is called, *loam.*

CHRISTINA.

Now, I can imagine how the process goes on: every year a new crop of buds springs up and dies, till there is enough of soil produced to bring the moss to maturity.

MRS. R.

Sometimes this is the case, and at others, as soon as a thin layer of this soil is formed from the withered moss-buds, a crop of lichens makes its appearance, and goes through the same process of growth and decay; and, if other circumstances are favourable, the soil soon accumulates to a sufficient depth for grass and such plants as can grow in little earth. In process of time, the

* This discovery we owe to Mr. Drummond, of the Cork Botanic Garden. Linnæus thought it was a peculiar species of *byssus.*

grass also dies, and, the soil being thence increased, wall-flower, snapdragon, and red valerian succeed. On old ruins you may even see trees growing on soil which has been thus accumulated in a succession of years, and particularly trees that have winged seeds, such as the ash.

CHRISTINA.

Oh, I am so delighted with this history of the origin of soil, and of the lichens and moss that make old walls so interesting!

EDWARD.

I should have liked it better, though, if we could have discovered whence the first seeds came of the green silky-looking moss-buds on the new-built wall.

MRS. R.

This is one of the mysteries of nature, which are continually interrupting our inquiries in every department of study, intended, perhaps, by a wise Providence, to humble our pride by making us feel our weakness.

EDWARD.

I confess that, were it not for the wild and improbable fancy of a central fire, and its capricious

expansions of upheaving rocks, these fine speculations respecting the action of water and weather on rocks, and the interesting history of the origin of gravel and soil, would strongly tempt me to become a disciple of Dr. Hutton.

MRS. R.

You must recollect, however, that all that I have just told you is not derived from the Huttonian system, though it partly accords with it; and I may say the same of the subjects which I shall next introduce to your notice, in continuing the subject of the destruction of rocks and the inequalities of the surface of the earth: but this, if you please, we shall leave till the next opportunity.

CONVERSATION SEVENTH.

ORIGIN OF GLACIERS AND DESERTS.

EDWARD.

While thinking over what you told us yesterday of the destruction of rocks, I have been puzzling myself about the glaciers of Mont Blanc *descending* with the fragments that fell upon them; for I have always understood a glacier to be a great mass of ice and snow frozen together, in the Alpine valleys, but remaining stationary where it is formed, and suffering no change but that of increase.

MRS. R.

Then you are not acquainted with the whole history of the glaciers. The principal glaciers are sometimes of the immense extent of twelve or fifteen leagues long, one league broad, and from

eighty to six hundred feet thick, lying in high valleys open at the lower extremity, but closed at the upper by the sides of the mountain. Smaller glaciers occur among the Alpine ridges, at very high elevations, composed entirely of frozen snow, from which, as from a sea, the loftiest peaks only are seen projecting, like abrupt and craggy islands.

CHRISTINA.

I should like to see a sketch of this wild scenery.

MRS. R.

I dare say we shall find it in some of the books of travels. From these come down those sudden falls of accumulated snow called *avalanches,* and now poetically known by the term *lauwine,* from the fine figure applied to the decline of empires:

> "Nations melt
> From power's high pinnacle when they have felt
> The sunshine for awhile, and downward go,
> Like lauwine loosened from the mountain's belt."

EDWARD.

I now perceive how those very high glaciers may fall. The continued accumulation of snow, increasing every winter, at last makes them, if I

may say so, top-heavy, and, giving way for want of support, they must be precipitated into the valleys beneath.

MRS. R.

And of course, in their fall, they carry down, together with themselves, such portions of the projecting crags as are unable to resist their passage. In other instances, the snow-water which is produced in summer, filters into the crevices of a glacier, and, being frozen in the succeeding winter, loosens, and detaches fragments of the frozen snow, in the same manner as fragments of rocks are detached under similar circumstances.

CHRISTINA.

It must be very grand to see one of those masses of frozen snow come down from the lofty side of an Alpine mountain, dashing down every thing that opposes its course, and rolling along like a huge snowball.

MRS. R.

Grand as the sight must be, it is extremely dangerous to the inhabitants of the subjacent valleys. Saussure says that, on the Col de Geant, the fall of avalanches is most frequent and

awful; and, during his stay in that neighbourhood, he says that, without exaggeration, he did not pass an hour without seeing or hearing one precipitated with a noise like thunder, either from Mont Blanc or some of the neighbouring heights. Saussure, indeed, is the least given to exaggeration of any traveller I know.

EDWARD.

That is a circumstance of much moment in descriptions of whatever is wonderful and uncommon.

MRS. R.

Were this not his character, we might hesitate to credit his history of the great avalanche, that, sixty years before his visiting the Vallée de Ferret, had been loosened and thrown down from an Alpine summit in the vicinity, and buried in its ruins the houses and cattle in the valley, and during all that period had constantly continued to pour down.

EDWARD.

I see nothing incredible in this; for the fragments would be detached so long as the causes continued to operate.

MRS. R.

There is another cause of avalanches, which is well worthy of notice. It will be obvious, from the great thickness of glaciers, that they must effectually protect the surface of the earth over which they lie, from the action of the external air; and, as the medium heat of the earth is sufficiently high to preserve springs from freezing, it will follow that the surface of the ground covered by a glacier will be above freezing in winter as well as in summer.

EDWARD.

Oh! I can see at a glance what will be the consequence of this; for the snow, in contact with the warm earth, must melt, and, by the gradual melting of the lower surface, the upper parts will lose their support and sink down.

MRS. R.

Precisely: and sometimes this produces tremendous chasms, to all appearance bottomless, by which the passage over the glaciers is interrupted; and the danger to the Chamois hunters and to Alpine adventurers is often greatly increased by the subsequent filling-up of those chasms with fresh snow, which lures the traveller

to destruction by its smooth and unbroken surface.

CHRISTINA.

I recollect reading an account of several guides being lost in this way, in the first attempts made to reach the summit of Mont Blanc.

MRS. R.

An important effect of this sinking of the glaciers by the melting of their lower surface is, that their upper part is continually advancing towards a lower level, till, by degrees, they are entirely melted. This incessant melting of those masses of frozen snow is one of the chief sources of Alpine streams and rivers, so that, while they may be in one sense looked upon as the deserts of the Alps, in another they may be said to be the great magazines of fertility to the valley-grounds below.

EDWARD.

When you just now mentioned deserts, it struck me that the Geologists will find some difficulty in accounting for their origin and formation.

MRS. R.

Not so much, perhaps, as you imagine; for

what are deserts, however extensive, more than great beds of sand, with a very scanty vegetation, if any, to cover their surface, and interspersed with a few fertile spots, usually adorned with palm-trees, and in the vicinity of springs.

CHRISTINA.

If the little moss-buds would grow there as they do on walls, a good soil might soon be formed, and then, as the Scriptures beautifully express it, "the desert would rejoice and blossom like the rose."

MRS. R.

It would appear that there is not an equal supply of moss-seeds in the deserts as with us; in Thibet, the inhabitants fertilize the desert soil artificially, by laying it under water in winter, which prevents the sand from being carried about by the winds.

EDWARD.

That would, indeed, be an improvement; but where are the Africans to obtain water to cover the Great Sahara, which is said to be three thousand miles in length, and twelve hundred in breadth? or the Persians, to inundate the Mek-

ran, which is said to be a hundred thousand miles square? *

MRS. R.

This would, indeed, be a chimerical project! I must set you right, however, in one point, respecting the natural history of deserts: you are not to suppose that they are smooth plains of sand, uniform in level, which I believe is the common idea of a desert. They are frequently diversified with hills of sand blown together by the winds, and that in proportion to the lightness of the sand and the violence of the winds; and sometimes there are rocky mountains, as in other parts of the world: a striking example of which occurs in the desert west of the Nile, where a natural mountain barrier has intercepted the drift-sand from the Sahara from covering the beautiful Oasis of Ammon, with its green pastures and palm-trees.

EDWARD.

I recollect that in Suffolk there are sand-hills

* Kinneir's Persia, p. 122.

of the same kind as I suppose those of the desert to be.

MRS. R.

Right, my dear: those hills are formed by the winds sweeping along through the plains of Cambridgeshire, and piling up the Suffolk sands. In Scotland there is a good instance of the same occurrence, between Irvine and Ardrossan; but those are nothing to the hills of drifted sand in other parts of the world.

Kinneir tells us, that in the province of Seistan, in Persia, which is flat, sandy, and thinly inhabited, a wind blows for nearly a third of the year with such violence, as to overwhelm with clouds of sand whole houses, gardens, and fields; and Pallas says the same of the moving sand between the mouth of the rivers Oural and Volga.

Humboldt gives a similar account of the sandy plain near Vera Cruz, in which hills are filled up to the height of nearly forty feet by the north winds, which blow from October to April. Every year, of course, these change their form and situation, and the sand thus accumulated covers the native rock to so great a depth, that no stone is to be met with in the vicinity.

EDWARD.

I recollect reading, in Bruce's Travels, an extraordinary account of a cloud of sand having blown over the traveller and his party.

CHRISTINA.

And Dr. Darwin has taken advantage of this to give a grand poetical description of the army of Cyrus perishing in the desert of Lybia.

MRS. R.

Well done: this is, indeed, to turn your reading to advantage; and I shall only add, that Mr. Salt, a recent traveller, says that, on the African side of the Straits of Babelmandel, the sand is carried up by the winds in the shape of pillars, which are frequently observed sweeping in different directions across the plain. Denon tells us, also, that though the banks of the Nile are partly protected by a chain of hills from the drifting sands of the Lybian Desert, yet an occasional strong wind sometimes overwhelms part of the country, leaving no other marks of vegetable life than the tops of a few palm-trees, together with the roofs of

may say so, top-heavy, and, giving way for want of support, they must be precipitated into the valleys beneath.

MRS. R.

And of course, in their fall, they carry down, together with themselves, such portions of the projecting crags as are unable to resist their passage. In other instances, the snow-water which is produced in summer, filters into the crevices of a glacier, and, being frozen in the succeeding winter, loosens, and detaches fragments of the frozen snow, in the same manner as fragments of rocks are detached under similar circumstances.

CHRISTINA.

It must be very grand to see one of those masses of frozen snow come down from the lofty side of an Alpine mountain, dashing down every thing that opposes its course, and rolling along like a huge snowball.

MRS. R.

Grand as the sight must be, it is extremely dangerous to the inhabitants of the subjacent valleys. Saussure says that, on the Col de Geant, the fall of avalanches is most frequent and

awful; and, during his stay in that neighbourhood, he says that, without exaggeration, he did not pass an hour without seeing or hearing one precipitated with a noise like thunder, either from Mont Blanc or some of the neighbouring heights. Saussure, indeed, is the least given to exaggeration of any traveller I know.

EDWARD.

That is a circumstance of much moment in descriptions of whatever is wonderful and uncommon.

MRS. R.

Were this not his character, we might hesitate to credit his history of the great avalanche, that, sixty years before his visiting the Vallée de Ferret, had been loosened and thrown down from an Alpine summit in the vicinity, and buried in its ruins the houses and cattle in the valley, and during all that period had constantly continued to pour down.

EDWARD.

I see nothing incredible in this; for the fragments would be detached so long as the causes continued to operate.

MRS. R.

There is another cause of avalanches, which is well worthy of notice. It will be obvious, from the great thickness of glaciers, that they must effectually protect the surface of the earth over which they lie, from the action of the external air; and, as the medium heat of the earth is sufficiently high to preserve springs from freezing, it will follow that the surface of the ground covered by a glacier will be above freezing in winter as well as in summer.

EDWARD.

Oh! I can see at a glance what will be the consequence of this; for the snow, in contact with the warm earth, must melt, and, by the gradual melting of the lower surface, the upper parts will lose their support and sink down.

MRS, R.

Precisely: and sometimes this produces tremendous chasms, to all appearance bottomless, by which the passage over the glaciers is interrupted; and the danger to the Chamois hunters and to Alpine adventurers is often greatly increased by the subsequent filling-up of those chasms with fresh snow, which lures the traveller

to destruction by its smooth and unbroken surface.

CHRISTINA.

I recollect reading an account of several guides being lost in this way, in the first attempts made to reach the summit of Mont Blanc.

MRS. R.

An important effect of this sinking of the glaciers by the melting of their lower surface is, that their upper part is continually advancing towards a lower level, till, by degrees, they are entirely melted. This incessant melting of those masses of frozen snow is one of the chief sources of Alpine streams and rivers, so that, while they may be in one sense looked upon as the deserts of the Alps, in another they may be said to be the great magazines of fertility to the valley-grounds below.

EDWARD.

When you just now mentioned deserts, it struck me that the Geologists will find some difficulty in accounting for their origin and formation.

MRS. R.

Not so much, perhaps, as you imagine; for

what are deserts, however extensive, more than great beds of sand, with a very scanty vegetation, if any, to cover their surface, and interspersed with a few fertile spots, usually adorned with palm-trees, and in the vicinity of springs.

CHRISTINA.

If the little moss-buds would grow there as they do on walls, a good soil might soon be formed, and then, as the Scriptures beautifully express it, "the desert would rejoice and blossom like the rose."

MRS. R.

It would appear that there is not an equal supply of moss-seeds in the deserts as with us; in Thibet, the inhabitants fertilize the desert soil artificially, by laying it under water in winter, which prevents the sand from being carried about by the winds.

EDWARD.

That would, indeed, be an improvement; but where are the Africans to obtain water to cover the Great Sahara, which is said to be three thousand miles in length, and twelve hundred in breadth? or the Persians, to inundate the Mek-

ran, which is said to be a hundred thousand miles square? *

MRS. R.

This would, indeed, be a chimerical project! I must set you right, however, in one point, respecting the natural history of deserts: you are not to suppose that they are smooth plains of sand, uniform in level, which I believe is the common idea of a desert. They are frequently diversified with hills of sand blown together by the winds, and that in proportion to the lightness of the sand and the violence of the winds; and sometimes there are rocky mountains, as in other parts of the world: a striking example of which occurs in the desert west of the Nile, where a natural mountain barrier has intercepted the drift-sand from the Sahara from covering the beautiful Oasis of Ammon, with its green pastures and palm-trees.

EDWARD.

I recollect that in Suffolk there are sand-hills

* Kinneir's Persia, p. 122.

of the same kind as I suppose those of the desert to be.

MRS. R.

Right, my dear: those hills are formed by the winds sweeping along through the plains of Cambridgeshire, and piling up the Suffolk sands. In Scotland there is a good instance of the same occurrence, between Irvine and Ardrossan; but those are nothing to the hills of drifted sand in other parts of the world.

Kinneir tells us, that in the province of Seistan, in Persia, which is flat, sandy, and thinly inhabited, a wind blows for nearly a third of the year with such violence, as to overwhelm with clouds of sand whole houses, gardens, and fields; and Pallas says the same of the moving sand between the mouth of the rivers Oural and Volga.

Humboldt gives a similar account of the sandy plain near Vera Cruz, in which hills are filled up to the height of nearly forty feet by the north winds, which blow from October to April. Every year, of course, these change their form and situation, and the sand thus accumulated covers the native rock to so great a depth, that no stone is to be met with in the vicinity.

EDWARD.

I recollect reading, in Bruce's Travels, an extraordinary account of a cloud of sand having blown over the traveller and his party.

CHRISTINA.

And Dr. Darwin has taken advantage of this to give a grand poetical description of the army of Cyrus perishing in the desert of Lybia.

MRS. R.

Well done: this is, indeed, to turn your reading to advantage; and I shall only add, that Mr. Salt, a recent traveller, says that, on the African side of the Straits of Babelmandel, the sand is carried up by the winds in the shape of pillars, which are frequently observed sweeping in different directions across the plain. Denon tells us, also, that though the banks of the Nile are partly protected by a chain of hills from the drifting sands of the Lybian Desert, yet an occasional strong wind sometimes overwhelms part of the country, leaving no other marks of vegetable life than the tops of a few palm-trees, together with the roofs of

buildings, which only add to the dreary aspect of desolation.

EDWARD.

It does not appear to me that such immense plains of sand could have been washed from rocks by any other agent than the sea at the deluge.

MRS. R.

Such, I believe, was the opinion of Dr. Hutton, or rather that the deserts are part of the strata which the heat of the central fire had not power to consolidate while it remained at the bottom of the sea. It strengthens this notion, that the sand of the desert is very fine, like sea-sand.

EDWARD.

Now that I think of it, we did not take notice of the action of the sea upon rocks, when we were discussing the influence of torrents and rivers.

MRS. R.

That is a very important point in geological inquiry, and I may tell you, that though in particular situations the sea is found to encroach upon the land to a remarkable extent, yet upon the whole it has a tendency, by the sand, shells, and

other matters which it throws up, to make additions to the land, an effect which is increased by the mud carried down by rivers. This throwing up of sand-banks, you may remark, also, must shield the rocks on the sea-shore from the ravages of the waves.

EDWARD.

This is a view of the subject which, obvious as it is, never occurred to me.

MRS. R.

Such is usually the character of simple truths; but I shall give you an example of what may be considered the action of the sea, in the Isle of Ramsey, off the coast of Pembrokeshire, near St. David's. On each of the extremities, north and south, of the island, is an elevation consisting of rock of a very compact and durable structure, though the intervening rocks are slaty and soft. The western front of each of the compact rocks projects into the sea far beyond the intermediate space of land, and it appears probable that the bay interposed between them has been cut out by the dashing of the waves against the crumbling slate, and that in process of time the whole mid-

dle part may be swept away, and the island separated into two, as the ancients conjectured was the origin of the separation of Sicily from Italy; and, from the similarity of the rocks on each coast, is strongly supposed to have been the origin of the separation of England from France, by the straits of Dover.

EDWARD.

I recollect, I think, that you mentioned some time ago, that the city of Calicut, in the East Indies, had been quite overflowed by the sea, and that ships now sail over its highest minarets.

MRS. R.

That is a well-known and interesting fact; and there is a similar instance nearer home, the town of Findhorn having been overflowed by the sea, and now washed by every tide. At St. Andrews, the famous castle, which was originally at some distance from the sea, now almost overhangs it; and, within the last century, the sea has made such an impression upon the sands of Barrey, on the north side of the Tay, that the light-houses at the entrance of the river have been from time to time removed about a mile and a quarter farther north, on account of the wasting

and shifting of these sandy shores; and the spot on which the outer lighthouse stood in the seventeenth century, is now two or three fathoms under water, and at least three-quarters of a mile within the flood-mark.

EDWARD.

The wearing-down of the shores in all those cases appears to have been gradual, in the same way as rivers undermine the soft cliffs beside which they run.

MRS. R.

Yes: but there are instances of the sea making sudden and violent eruptions, somewhat like the mountain torrents already noticed; which we have seen, as you recollect, spreading consternation and terror, rolling before them huge masses of rock, and burying whole tracks of country, with their towns and villages, in the wreck.

EDWARD.

I do not recollect, in my reading, of any instance in which the sea produced such catastrophes.

MRS. R.

Probably not: but they have unfortunately occurred, particularly in the Danish Islands, on the

coast of Sleswick, which are continually increasing by the rich mud thrown up by the sea on their coasts. This newly formed soil, however, has to be carefully protected by dikes, from extraordinary spring-tides or occasional overflowings of the sea of Jutland; and, before this method was devised, the settlers were in continual peril of destruction from the waves rolling in upon their fields, tearing away the grass which had bound their surface, and reducing them to mere banks of sand and mud. In the year 516, more than six hundred men were thus destroyed by the rush of the sea; in 1216, nearly ten thousand of the inhabitants perished from the same cause; and in eighty-four years afterwards, seven parishes in Nordstrand and Pellworm were destroyed. In 1362, the isles now called Fora and Syls, which before this were united, were completely separated by the sea. In 1634, there was another great overflow of the sea and a great tempest, which dissevered Pellworm and Nordstrand, and extended its ravages over the whole coast of Jutland, to the great consternation of the inhabitants.

EDWARD.

These facts, however, do not prove that the

sea is advancing generally upon the land, as in other parts the land is gaining, as you have told us, upon the sea.

MRS. R.

Of the latter circumstance there are several very striking instances recorded. Among others, Mr. Prony, a celebrated French engineer, tells us, that, in the course of two hundred years, the Delta, at the mouth of the river Po, has gained about nine miles upon the sea; and the sea which formerly washed the walls of Adria, was, even in the twelfth century, six miles from it, and in the seventeenth had nearly doubled that distance, but is now nearly twenty miles, the land making an average progress of advance upon the sea of between seventy and eighty yards.

EDWARD.

I now recollect a passage in Humboldt which shows the advance of the sea, and will contrast well with this interesting account of Mr. Prony, of the advance of the land. The traveller remarked, that, along the western coast of the Gulf of Mexico, were many oblong lakes of salt water, running parallel with the coast, and separated by long islets and tongues of land from the

sea, through which it occasionally breaks by transverse channels.

MRS. R.

But, if I recollect rightly, Humboldt does not affirm that the sea has advanced on the land, but is in doubt whether this has been the case, or that the land is advancing on the sea by the tides throwing up sand-banks and forming those islets. In a parallel instance, Pallas expressly says that, in the Crimea, all the salt lakes are only separated from the sea, of which they once formed a part, by low narrow bars of sand, which the sea, during violent tempests, throws up.

EDWARD.

I find that my memory has, indeed, deceived me, and I thank you for the correction.

CONVERSATION EIGHTH.

ORIGIN OF ISLANDS FROM CORAL AND VOLCANOS.

CHRISTINA.

I THINK I remember seeing it remarked in some book of voyages, that Otaheité, and all the islands of the South Sea, have been raised from the sea by insects; now, I cannot help thinking this, if true, to be very extraordinary.

MRS. R.

There can be no question of the truth of the fact, as we have the uniform testimony of every observer who has examined them, to confirm it.

CHRISTINA.

The insects which build the islands must either be very large or very numerous.

MRS. R.

The latter, and not the former, is the case; for the polypus animalculæ (we cannot with propriety call them insects), which manufacture coral and build islands, are minute and delicate in structure, and seem to have the power of encasing themselves with a hard crust for the purpose of protection.

EDWARD.

More, then, it would appear, like a snail or a shell-fish, than an insect.

MRS. R.

You are right; and you may judge of the number of a coral colony, from the extraordinary facts related by voyagers of unquestionable credit. Captain Flinders, for instance, tells us, that the quantity of coral reefs between New Holland, New Caledonia, and New Guinea, is such, that it might justly be called the Coralline Sea, there being here, for three hundred and fifty miles, in a straight line, a coral reef or barrier, uninterrupted by any large opening into the sea; and this reef is connected with others, so as altogether to make

an extent of nearly one thousand miles in length, and from twenty to fifty miles in breadth.

EDWARD.

I should like very much to see the little creatures at work upon such an immense mound.

MRS. R.

That would be impossible, as their work is slow and gradual; you might as well say you would like to see a snail at work in making its shell, or a rose-tree at work in making its flower.

EDWARD.

The process of the coral polypus, at least, has been explained, I presume.

MRS. R.

As to that, it is the same with the process of forming the snail-shell. The sea water always contains lime, as do the vegetables upon which the snail feeds; now, you know that, when lime meets with carbonic acid gas, it unites with it, and forms chalk, or limestone, or marble.

EDWARD.

All this is obvious; but I cannot conjecture where the coral animalcule, or the snail, gets the carbonic acid gas to unite with the lime.

MRS. R.

So you have forgot your pretty chemical experiment of blowing through a glass tube into lime-water?

EDWARD.

Oh, no! but I did not know that a coral polypus, or a snail, breathed as I do.

MRS. R.

It seems to be a general law of all living things: they produce carbonic acid gas in a way similar to ourselves; and it is probable that in the snail and the coral polypus this gas passes off from the surface of the body, where it meets with the lime that forms the basis of the shell; and this is cemented into a firmer substance by the slime of the animal which is present at the same time. Some sorts of coral, you know, are so hard as to take a fine polish, and are made into trinkets; but they all

consist of lime, carbonic acid gas, and the slimy substance of the polypus for a cement.

CHRISTINA.

I can understand this perfectly, and I am quite delighted with this history of coral, but had no notion that I should meet with such things in Geology.

EDWARD.

I cannot, however, conceive well how such animals concert together to form a reef or an island, as I presume they are no less stupid than snails seem to be.

MRS. R.

With respect to their intelligence, we can derive our information only from their works; and, from what I shall tell you, it must be concluded, either that they are very wise and skilful, or that they are immediately directed in their operations by an Allwise Providence.

EDWARD.

In the formation of the shell, at least, there is no intelligence manifested on the part of the little manufacturer: it is only the result of a natural

chemical process, over which it seems to have little, if any, control.

MRS. R.

Right: but what I refer to is an union of purpose and design in all the individuals of a coral colony, which you will confess to be surprising, when I tell you that most, if not all, of the coral reefs are built in the form of a crescent, and sometimes of a circle, with the back to the sea, as if the coral animalcules were aware of the properties of the arch, and knew that it would resist the dashing of the waves better than a straight line.*

EDWARD.

This is, indeed, most wonderful.

MRS. R.

The wonder is increased when we find that the back of the coral crescent is generally directed towards the quarter from which storms most frequently come. Now, these are circumstances

* See the Voyages of Cooke, Flinders, &c., *passim*.

which cannot be explained otherwise than by the operation of intelligence and design; for the sea would naturally beat in the back of the crescent, and, by reversing it, turn its bosom to the waves in form of a bay.

EDWARD.

I am so interested in this singular history of corals, that I should like to know something more minutely respecting the progressive building of those crescent-formed reefs.

MRS. R.

I am happy to be able, perhaps, to satisfy you in this, by the assistance of the accurate Captain Flinders, from which I dare say Christina will read you the extract I have here marked.

CHRISTINA.

I shall do that most willingly. "It seems to me," the captain says, "that, when the coral animalcules cease to live, their structures adhere to each other, by virtue either of the glutinous remains within, or of some propensity in the salt water; and, the interstices being gradually filled

up with sand and broken pieces of coral washed up by the sea, which also adhere, a mass of rock is at length formed. Future races of these animalcules erect their habitations upon the rising banks, and die in their turns, to increase, but principally to elevate, this monument of their wonderful labours.

"The care taken to work perpendicularly in the early stages, would mark a surprising instinct in these diminutive creatures. Their wall of coral, for the most part built in situations where the winds are constant, being arrived at the surface, affords a shelter, to leeward of which their infant colonies may be safely sent forth; and to this, their instinctive foresight, it seems to be owing, that the windward side of a coral reef, exposed to the open sea, is generally, if not always, the highest part, rising almost perpendicularly, sometimes from the depth of two hundred, and perhaps many more, fathoms.

"To be constantly covered with water seems necessary to the existence of the animalcules, for they do not work, except in holes upon the reef, beyond low-water mark; but the coral sand, and other broken remnants thrown up by the sea, adhere to the rock, and form a solid mass with it, as

high as the common tide reaches. That elevation surpassed, the future ones, being scarcely covered, lose their adhesive property, and, remaining in a loose state, form what is usually called a *key*, upon the top of the reef.

"The new bank is not long in being visited by sea-birds; salt plants take root upon it, and a soil begins to be formed; a cocoa-nut, or the berry of a pandanus, is thrown on shore; land birds visit it, and deposit the seeds of plants, shrubs, and trees; every high tide, and still more every gale, adds something to the bank; the form of an island is gradually assumed; and, last of all, comes man to take possession.

"Half-way Island is well advanced in the above progressive state; having been many years, probably some ages, above the reach of the highest spring tides, or the wash of the surf in the heaviest gales. I distinguished, however, in the rock which forms its basis, the sand, coral, and shells formerly thrown up, in a more or less perfect state of cohesion. Small pieces of wood, pumicestone, and other extraneous bodies, which chance had mixed with the calcareous substances when the cohesion began, were inclosed in the rock."

MRS. R.

I dare say both of you know that the Red Sea derives its name from the great number of red coral-banks, that give a colour to the waters; and it is worth stating, in confirmation of Christina's first remark on this subject, that Dr. Forster, who accompanied Captain Cooke, expressly says, that the process of which you have just read the account, is "the most probable cause of the *origin of all the tropical low isles over the whole South Sea.*" In the Straits of Gundy, and within one range of the eye, these islands are seen in all the stages of formation, first in low reefs and shoals, as just described.

EDWARD.

But this is not, I should think, the origin of many other islands, in other parts of the ocean.

MRS. R.

No, my dear: some of these have been formed by the sea breaking through narrow necks of land, as we formerly mentioned to be the supposed origin of our own island; some have arisen from sand-banks, from sunken rocks gradually co-

vered with sea wreck; and some have been violently thrown up by volcanos.

EDWARD.

This last is a proof of the eruption of rocks in a melted state, which Dr. Hutton, I think, would much delight and triumph in.

MRS. R.

It undoubtedly gives much plausibility to some parts of his reasoning, and would, perhaps, be conclusive, were the instances of such erupted islands, as was formerly remarked of volcanos, not so very few, that we cannot found upon them a general argument for all rocks. The island of Teneriffe was probably produced by a volcano, although I am not aware that it is known at what period it was formed; but we have genuine records of the appearance of several of these volcanic islands; among others, Mr. Barrow tells us, that, in 1757, eighteen small islands appeared above the surface of the sea, near the Azores, at the termination of a tremendous earthquake, but gradually subsided, and at length disappeared.

CHRISTINA.

Ah! I am so sorry they disappeared. The coral islands, with their rich soil and pretty cocoa-nuts, are the most interesting still.

MRS. R.

The volcanic islands seem all to be rather unstable, and not to be trusted. Professor Pallas tells of one that appeared in 1790, in the sea of Asoph, about three hundred yards from the shore, after loud thunder and subterraneous noises. "Then," he says, "after an explosion like that of a cannon, an island, about the size of a large antient tumulus, rose from out of the sea, which in that part was from twenty-five to thirty feet deep. The island, which was about six hundred feet in circumference, appeared to raise itself, to break into chasms, and to throw out mud and stones, till smoke and flame at length broke forth: the perpendicular height of the island was about twelve feet. There was an amazing swell of the sea during the whole process, which lasted two hours; and, in the course of the day, two earthquakes were felt at the distance of fifty leagues. The

final dimensions of the island were four hundred and thirty feet in length, two hundred and eighty-eight in breadth, and seven in height; but the following year the island disappeared." The island of Sabrina arose in the Azores, in 1811, in view of his majesty's ship Sabrina, whence it was called; but in a few months it was engulfed.

EDWARD.

And have all the volcanic islands disappeared in a similar manner?

MRS. R.

No, no: I told you a little while ago of the island of Teneriffe, which had been stationary, at least, for some hundred years.

EDWARD.

But its history, you said, is not known; what I meant was, whether any of those whose history is known, remain permanent.

MRS. R.

There are several instances of this: for example,—in the year 1707, a new volcanic island was formed in the Bay of St. Erini, in the Medi-

terranean Sea, about twenty-eight leagues to the north of Crete. An earthquake had been very extensively felt in St. Erini, two days previously to the appearance of the volcanic island; but no earthquake took place after its first appearance, and the island continued to increase very sensibly both in breadth and in height, without any other alarming circumstance; and, after a continued agitation of the sea for some days preceding, with the casting-up of many minerals, particularly sulphur, a chain of black rocks arose, and soon joined themselves to the new island. Three days afterwards, flames burst out from the newly-formed island, preceded by submarine murmurings; these phenomena continued, with occasional showers of fire-dust (similar circumstances to which took place in the late eruptions of St. Vincent's), for a month, and, having then subsided for a time, were renewed with increased violence during the three following months; at which time the circumference of the volcanic island appeared to be about three miles, and its height from thirty to forty feet. The island continued to increase till May, 1708, at which time it was nearly of the following dimensions: in height, two hundred feet; in circumference, five miles; in breadth, where

broadest, one mile. On the north side of Saint Erini, there was formed a similar volcanic island, in 1426; and the same island was increased, in 1427, by another submarine eruption, and again in 1650.

EDWARD.

Are these submarine eruptions the only instances on record?

MRS. R.

No; other instances might be quoted, but these are sufficient for our present purpose. However, it is right you should know that such phenomena are not confined to the sea, as we have volcanic mountains of great height sometimes produced suddenly on land.

CHRISTINA.

It would be awfully grand to see such a phenomenon.

MRS. R.

Humboldt's account of the volcano of Jurullo, in Mexico, is one of the best examples of this. It made its appearance in the year 1759, breaking out in the province of Valladolid, on the western declivity of the Cordilleras, at the distance of thirty-six leagues from the coast, and more than

forty-two leagues from any volcano now in activity, and suddenly formed a mountain of scoriæ and cinders, rising about one thousand six hundred feet in height above the level of the surrounding plain, in the midst of many hundred small burning cones. In another part of the same province, and in the same year, a tract of land, three or four miles square, was raised above the level of the surrounding ground, the limits of which catastrophe may be seen at the present day, by the fractured state of the strata. The heat of the crevices in these fractured strata is even now nearly that of boiling water; and subterraneous murmurings are heard on the spot, which, it is probable, proceed from water in a state of ebullition, for there was an ejection of mud and matter at the original eruption of the volcano, in 1759. These subterraneous murmurings of volcanos are sometimes heard like the noise of artillery, at the distance of sixty or seventy leagues. Sir William Hamilton has also given a highly interesting account of the formation of Monte Nuova, a volcanic mountain three miles in circumference at its base, which arose in forty-eight hours, in 1538, in the middle of a plain north-west of Naples.

EDWARD.

The lava which volcanos eject must frequently, when in great quantity, alter the appearance of a country and modify its inequalities of surface.

MRS. R.

Undoubtedly: and though, from the smallness of the number of volcanos, compared with the extent of the globe, we cannot consider the influence of these in so general a view as the action of water, it would be wrong to overlook them in a geological inquiry.

EDWARD.

I should like to know whether the number of volcanos has been ascertained.

MRS. R.

Taking the small ones along with the more extensive, there are about two hundred now, or were lately, in activity, though all of these do not eject lava, but many of them (particularly in South America) throw out great quantities of mud and water. When lava is ejected, the more fluid part of it runs in long streams, while the less fluid

portion stops at the edge of the opening, raises it all round, and forms a cone terminated by a crater. Thus, volcanos accumulate substances on the surface, that were formerly buried deep in the bowels of the earth, after having changed or modified their nature or appearances, and thus raise them into mountains. By these means they have formerly covered some parts of the continents, but have never raised up or overturned the strata through which their apertures pass, and have in no degree contributed to the elevations of great mountains which are not volcanic.

EDWARD.

It would be interesting to know something of the extent of the rocks formed by erupted lava.

MRS. R.

As to this, it is supposed that all the tract of country called *Campagna Felice*, between Naples and the Apennines, is covered with lava rocks, which are of different depths, according to the quantity of lava that has been thrown out. The two antient cities, Herculaneum and Pompeii, you are aware, were buried under the lava of Vesuvius, about two thousand years ago.

CHRISTINA.

I am ashamed to say that I forget how far they are from the mountain.

MRS. R.

Pompeii is five miles distant on the south-east, and Herculaneum is just at the foot of Vesuvius, on the west side. As they were both buried under the lava at the same time, it is clear that the surface of all the ground between them must have been volcanically formed since the commencement of that eruption; and it has been found that Pompeii is now from ten to twelve feet below the actual surface, and that Herculaneum is now not less than from seventy to a hundred and twelve feet beneath the surface; but the pavement of Pompeii was found to be of lava, and under the foundation of the town is a deep stratum of lava, so that, probably, this part of Italy is, to a considerable depth, of volcanic origin. [See the Plates of Pompeii.] Castel-a-Mare (near which stood the antient Stabiæ, which was buried by the eruption that destroyed the elder Pliny), is still more distant from Vesuvius than Pompeii itself. Sir William Hamilton says,

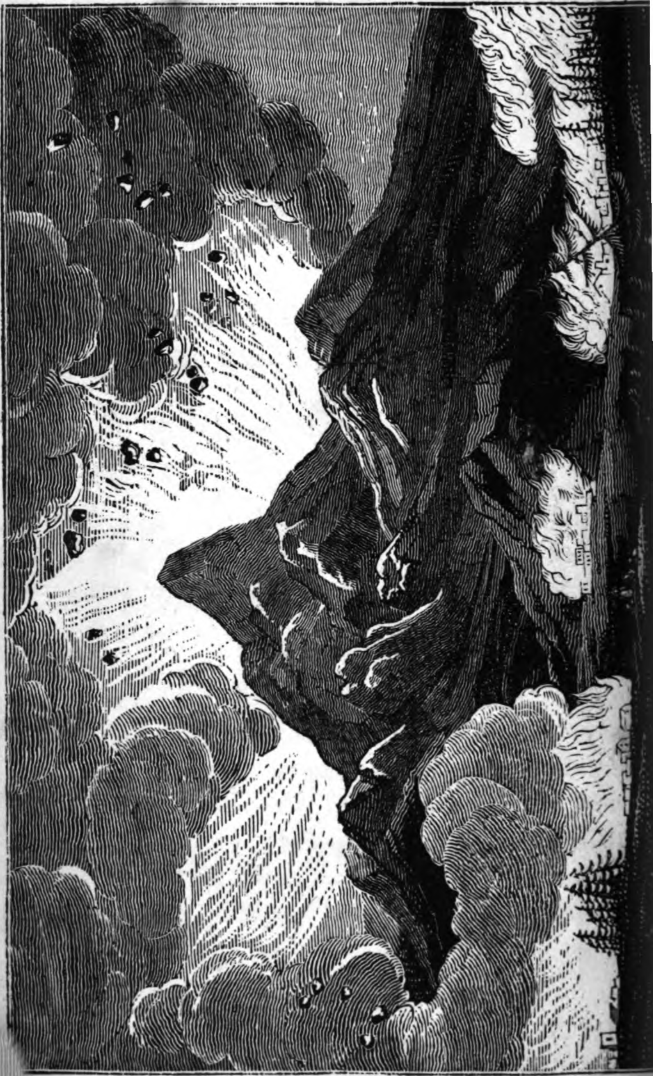
that some of the cinders covering Pompeii are eight pounds in weight; yet these must have been projected from Vesuvius, together with the lighter ashes, in the form of a shower.

EDWARD.

The throwing of such heavy substances to a distance must be very dangerous to the inhabitants.

MRS. R.

Undoubtedly; and the more terrible, that they are ejected red hot. M. Dolomien says, that he saw the crater of Stromboli, in the Lipari Islands, during the night, at intervals of seven or eight minutes, dart up burning stones to the height of more than a hundred feet, some of which rolled to the sea, and others fell back into the crater, while each explosion was accompanied by a burst of red flame. The ashes from Vesuvius often fall at the distance of a hundred miles; the stones which it ejects are sometimes more than a hundred feet in circumference,—while streams of lava, a mile wide and twelve feet deep, forming a river, if I may say so, of liquid fire, are not uncommon.



CHRISTINA.

The sight of such a river would be very grand, were it not for the terror and dreadful alarm which it must spread over the country.

MRS. R.

You will see a faint representation, in the plate, of the volcano of Amagadasci, in Japan; but the mud volcanos of America are, perhaps, still more terrific agents of destruction. When, for example, the volcano of Carguairazo fell down, on the night of the 16th July, 1698, it overflowed, with mud and slime, about eighteen miles square of the adjacent country, and destroyed so many of the inhabitants, that their bodies were buried in heaps; and, on the 4th of February, 1797, about forty thousand persons were destroyed by the water and mud thus ejected.

EDWARD.

I do not recollect that you told us any thing of the lava rocks when you described our cabinet.

MRS. R.

No, my dear; for there is no specimen in it, as

it was selected by a violent Wernerian; and, because volcanos do not accord well with Werner's theory, his disciples keep them as much as possible out of view, and even labour to show that lava is a product of water.

EDWARD.

But that is not the proper way to arrive at truth, and is a most disingenuous mode of attempting to support their theory.

MRS. R.

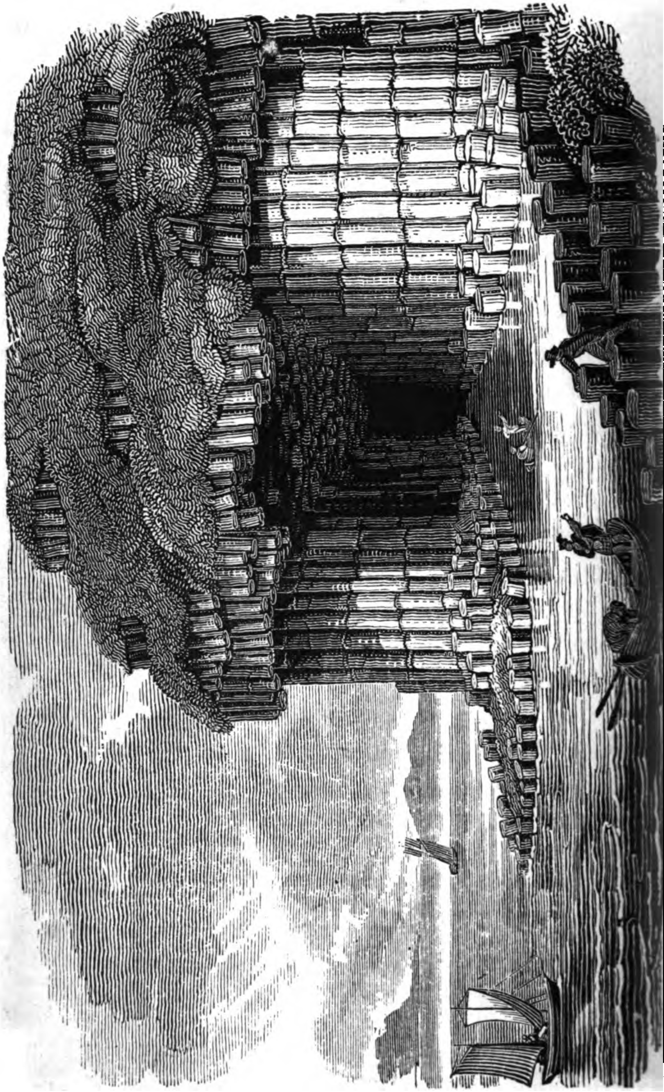
Your observation is perfectly just. I have now procured you, however, a fine specimen of lava from Iceland, which, though externally a very cold country, seems to have an immense fire under it.

EDWARD.

The specimen reminds me very much of basalt.

MRS. R.

Yes; and the Huttonians, in accordance with their theory, exert all their ingenuity, not only to prove the resemblance, but the identity. The magnificent columns of basalt, for example, which overlook the sea on the north of Ireland, and ar



well known by the name of the Giant's Causeway, are supposed to have been formed by the eruption of lava from some grand submarine volcano of former ages, now extinct. It is fancied to have been somewhere in the channel of the present sea, between the Causeway and the Island of Staffa, the columns of which [see the Plate of Fingal's Cave, in Staffa] are thought to have been formed by the same volcano, as well as the crag of Ailsa, and, perhaps, the trap-rocks of Sky.

EDWARD.

And is there in reality no difference between lava rocks and basalt?

MRS. R.

There are some rather nice distinctions given: such as, that the lava contains no water of crystallization, like the basalt; but I think that, whether they are the same or not, they are so very similar, that we may safely agree with the Huttonians as to their origin being from materials melted by fire.

EDWARD.

I would say that, in this view of the subject, if there are many such strong indications of extinct

volcanos as this of Staffa and the Giant's Causeway, the objection to the Huttonian theory, which you formerly mentioned as taken from the small number and extent of existing volcanos, will be in some measure obviated.

MRS. R.

There is considerable weight, I confess, in your remark; and, with respect to the extent of basaltic rocks, they, perhaps, cover more of the earth's surface than granite, sandstone, or any of the other rocks.

EDWARD.

Are there any other instances of this as striking as that of Staffa and the Causeway?

MRS. R.

There are very extensive rocks of this character in Auvergne, Saxony, and other places, but none so finely columnar. M. Boué, a recent French author, in a Geological Survey of Scotland, supposes that all the basaltic rocks, from Dunbar to the Firth of Clyde, a distance of about a hundred miles, are the production of an immense submarine volcano, which he thinks must

have been somewhere in East Lothian, though it might, as I would suggest, be more plausibly located somewhere in the high grounds, near Falkirk, Bathgate, or Carnwath.

CHRISTINA.

I do not know the geography of the two latter places you mentioned.

MRS. R.

You will readily find them in your maps, about half way between Edinburgh and Glasgow.

EDWARD.

Is it on account of the fewness of their number that you have not considered the effect of earthquakes in producing inequalities on the surface of the earth?

MRS. R.

That was my chief reason; otherwise I should have mentioned them before this; but, now that you have discovered something to confirm Dr. Hutton's theory from volcanos, I think we may advantageously consider what support it derives from earthquakes.

EDWARD.

I anticipate that the inquiry will be very interesting.

MRS. R.

The most interesting fact relating to earthquakes, in a geological view of the subject, is their evident close connection with volcanos. The appearance, for example, of the eighteen volcanic islands in the Azores, formerly mentioned, was preceded by a tremendous earthquake, which continued eight days, and a similar circumstance occurred, you may recollect, in the sea of Asoph. In the vicinity of Ætna and Vesuvius, earthquakes are almost uniformly felt before an eruption. In 1783, about the end of January, flames broke out from the sea, thirty miles off Cape Reihianes, at the south-west extremity of Iceland, and continued to burst forth during several months. In June, earthquakes shook the whole of the island, the flames from the sea disappeared, and a dreadful volcanic eruption occurred at the Skaptaa Jokul, which is nearly two hundred miles from the point whence the eruptions took place in the sea. A somewhat similar occurrence, though unaccompa-

nied with any of the tremendous phenomena above described, is reported to have taken place, in 1755, at Sutton, in Bedfordshire. A pond in that town, in which there had been but little water for some weeks, suddenly filled, and a copious sediment was thrown up from the bottom, at the precise time of the great earthquake at Lisbon.

EDWARD.

You formerly mentioned it as having been supposed that the sea had washed away the neck of land which united Britain with France, and that a similar isthmus was supposed to have joined Sicily to Italy;* but would not it be more plausible to suppose that these straits were formed by some earthquakes?

MRS. R.

This is no new supposition, though I give you credit for suggesting it. Many consequences of a similar kind have been attributed to earthquakes; and, though they often appear plausible enough, it would be better if there were some historical record of the events.

---

* See OVID, Metamorphoseon, xv. 290, and Claudian de Rapt. Proserpinæ, I.

EDWARD.

Geology, indeed, so far as I have seen of it, is particularly deficient in historical record, and has to trust much to fancy and conjecture.

MRS. R.

I dare say you will think it one of these conjectures, to be told that the Mediterranean, before its union with the Black Sea and the ocean, was most probably a basin, much narrower and shallower than at present; for, though it received several considerable rivers, the Nile, the Rhone, and the Po; yet, since, even now, evaporation from its surface is sufficient to prevent it from overflowing, notwithstanding that the ocean flows into it at Gibraltar, and the Euxine at the Hellespont,—when it communicated with neither, evaporation must have kept its level much lower. When, therefore, by the rupture of the Thracian and of the African isthmus, which joined Ceuta with Gibraltar, the waters of both were poured in upon it, an immense pressure took place on its bed, under which it sunk, and fell into the interior cavity of the globe. During this tremendous convulsion, the Islands of Sicily, Sardi-

nia, Corsica, and those of the Archipelago, were torn off, and Italy was lengthened to its present shape. The neighbouring shores of France and Spain, and more especially those of Africa, as being much lower, as well as those of Greece and Asia, must have been inundated to a great extent, as is partly proved by the abundance of saline substances still found on the adjacent shores.

EDWARD.

This is certainly romance.

MRS. R.

Yet it is the grave opinion of such distinguished men as Tournefort, Pallas, and Kirwan; and, as I shall afterwards show you, they did not stop here, but extended their conjecture of the influence of these events half over Asia.

CHRISTINA.

That is much too wide a sweep for my poor fancy. M. Boué's Scotch volcano is quite extensive enough for me.

MRS. R.

Then, as I must leave you for the present, sup-

pose you try to make a sketch of this for your own amusement.

CHRISTINA.

I should prefer doing Staffa or the Giant's Causeway.

MRS. R.

Well, any thing, rather than idle away your time; as you will neither obtain amusement nor gain knowledge by being idle.

CONVERSATION NINTH.

ORIGIN OF VALLEYS, PLAINS, MARSHES, BOGS, AND LAKES.

MRS. R.

AFTER spending so much of your time upon the Huttonian account of the inequalities on the earth's surface, it is time that we should consider how the rival theory of Werner explains the subject.

EDWARD.

I hope that it will give us something better than Dr. Hutton's upheaving of the rocks by heat, and nothing worse than the beautiful account of the effects of weather and water in forming sand, gravel, and Delta lands, at the mouths of rivers.

MRS. R.

With respect to the first, it will, indeed, be very

different, if not better, and on the last point the two are, I believe, pretty nearly agreed.

CHRISTINA.

As Werner seems to have had a strong antipathy to fire (perhaps from being a descendant or relative of his celebrated countrywoman, Undine), we shall, at all events, hear nothing of those terrible fires and horrid chasms which were the delight of Dr. Hutton's fancy.

MRS. R.

Yes; you must now, if you wish to understand the Wernerian account, banish all notions of a central subterranean fire, with its expansions, explosions, and eruptions of melted rocks, and think only of the great world of waters which, before the dry land appeared, covered the whole globe from pole to pole, containing, dissolved in or mixed with its waters, all the materials of our present rocks.

EDWARD.

I recollect that, when you formerly told us about Werner's account of the formation of rocks by the waters depositing them, I puzzled myself to understand how mountains could be thus produced.

MRS. R.

Werner refers us to the natural and well-known laws of deposition and crystallization, for an explanation. In this view, even if we suppose the original nucleus or kernel of the globe to have been uniform, the deposition of crystals would soon produce inequalities, in the same way as we see occur in forming crystals of alum, which take the form of pyramids, somewhat like the peaks of Alpine granite, called needles.

EDWARD.

Ah! this is a much more natural explanation than the violent expansions and upheavings of Dr. Hutton. But can it be proved that the nucleus of the globe was uniform?

MRS. R.

It is quite impossible to say any thing positive on this point; and, for any thing that appears to the contrary, it might have been rough and unequal, just as well as smooth and uniform.

EDWARD.

Were that the case, the first crystals deposited

would adhere indifferently to all parts of the nucleus, and follow all its inequalities; and the rocks thus produced would be concave in the hollows, horizontal on the plains, and inclined or oblique only on the acclivities of eminences.

MRS. R.

Both accounts are, perhaps, sufficiently plausible; and, when we consider the magnificent scale on which the operations of nature are carried on, we must admire the genius of Werner in devising a theory that seems to agree so well with what we observe in the structure of the lofty peaks of granite, as well as with the wavings and varied dip of the strata of rocks. It even produces more sublime ideas of the power of God, to conceive him working silently, by secondary causes, in the mighty deep, than to vainly imagine him exerting his power to tear up the everlasting hills from their bases, and pile them up in all the wildness of ruin and desolation.

EDWARD.

I certainly prefer this account to that of Dr. Hutton; but a very strong objection to it suggests itself, from the nature of crystals. In all the pieces of granite, gneiss, hornblende, and syenite,

which you showed me, I remarked that the crystals of mica, felspar, and quartz, were mixed through the mass. Now, we never find, in chemical experiments at least, that more than the crystal of one substance, such as alum, or Epsom salts, or sugar-candy, unite together and form a mass.

MRS. R.

This is a very strong objection, indeed, which bears no less against Wernerian crystallization, than against Professor Jameson's supposition, that the whole globe is nothing more than one huge crystal, of which the different strata of rocks are the facettes.

EDWARD.

I fear we shall have to give up this theory of crystallization altogether.

MRS. R.

Not until you hear Werner's other causes of the earth's inequalities, which are partly founded upon this: for example, what he says of the subsidence or sinking down of rocks, after being left by the water, on the same principle that new houses settle in their foundations, both in consequence of their

own weight and of the weight of new materials heaped upon them.

EDWARD.

If I understand this rightly, Werner just reverses the Huttonian account of expansion, and would say, that the oblique or vertical position of many rocks, arose from the sinking of their inferior, and not from the elevation of their upper, extremities.

MRS. R.

This is his notion; and he thinks there would only be a slip or shift of the superincumbent rocks, and, in some cases, even of the materials of a mountain nucleus. In the case of single hills standing by themselves, this sinking would render their summits either conical, peaked, or rounded, according to the consistence of the rocks when it took place; while in ridges and chains, on the other hand, it would frequently render the summits oblong or globular, according to the situation of their bases.

EDWARD.

By this supposition, Werner will get rid of the consequences that would arise from the Huttonian

expansion of the rock strata being thrown out of their parallels, as would happen from the force from below diminishing in effect, in proportion to the number of strata to be elevated; while, by sinking or even shifting, the parallelism would be preserved, from the superior rock being supported by the one below it.

MRS. R.

You are a little two mathematical for me in this deduction; but I can give you some facts in proof, and facts are usually superior in force to the best speculative argument. Saussure, for instance, tells us of rocks arranged concentrically round a mountain, like the coats of an artichoke, but with this remarkable difference, that they are almost universally parallel, and, therefore, agreeing, as nearly as we can suppose, with a general subsidence of the mountain masses.

EDWARD.

This appearance, however, I should suppose, is not universally found in mountains.

MRS. R.

No: but Saussure repeatedly observed in

Switzerland, and particularly in the Vale of Chamouni and at St. Michel, that the rock strata resting upon others, become more and more inclined, as would follow from a general subsidence, while it is the very reverse of what we should expect from an expansive force.

EDWARD.

Perhaps we might lend Werner some assistance, by bringing in here the effect of running water in undermining rocks; as the tides and currents of his original ocean must have had some influence upon the rock strata, and might undermine the walls of mountains as soon as they appeared above water; in which case the outermost rocks would not only slip down from the others, but, from there being a deficiency below, would rise towards the horizon, in order to make it good.

MRS. R.

This is very well reasoned, my dear; or you might plausibly suppose that rain-water should insinuate itself between the several beds of rock, and, in consequence of accumulation or expansion by frost, would move the outermost rocks from their position.

EDWARD.

This would accord, in some measure, with what was formerly mentioned of the effects of frost.

MRS. R.

The sinking of the rocks, as explained by Werner, accounts as well for the formation of valleys as for the elevation of rocks, as the rocks would subside according to their differences of specific gravity; and this would be influenced both by the materials composing them, and according as they had been more or less exposed to the hardening effects of the dry air. In mountain masses, rocks would evidently be sooner laid bare on the retreat of the waters than in valleys, and it is not improbable, that the lower rocks in the valleys being at the same time rather soft, the more hard and heavy rocks above might sink in them to some extent. That occurrences of this kind took place, even in districts comparatively plain, has been inferred from the abundance of veins in countries of this description; for, as Mr. Greenough has well remarked, every subsidence implies a fault, and where there is no fault we may conclude there has been no subsidence.

CHRISTINA.

I must say I do not understand this so well as I think I understood Dr. Hutton's expansions and explosions.

MRS. R.

I can tell you one circumstance, which you cannot fail to understand. In the Isle of Wight, the strata over the chalk could not have been formed in a vertical but in a horizontal position, but since those are now vertical, and also parallel to the chalk, the inference is evident, that they must have been formed before the chalk subsided [see the Plate]. The inclined coal, also, which is covered with horizontal red marl, must have subsided before the marl was formed.

EDWARD.

This at least determines the relative age of the rock strata in question.

MRS. R.

It will also enable you to understand that beautiful part of Werner's theory in which he describes the deposition of the rocks formed after those which he denominated transition, and which he

conceives to have greatly modified the inequalities of the earth's surface. After the primitive waters, he supposes, had diminished to a pretty low level, they rose again, covering the system of inequalities then existing, and depositing the extensive formation of the floetz rocks. What is no less worthy of remark, he also thinks that at this time *the original lakes and rivers would frequently be banked across*, and a new system of rivers, valleys, and lakes, would often be the consequence.

EDWARD.

This will lead us back again to the hollowing-out of valleys and defiles by the currents of water; and, as the rivers of those times may have been much larger in some places than at present, we perhaps account by their means for the broad and deep channels which the waters that at present run through them seem quite inadequate to have formed.

MRS. R.

I think this is exceedingly probable, for there are no facts to prove that our present rivers have so far decreased in magnitude as the comparison of their actually known operation with those capacious channels would lead us to imagine.

Yet there are some circumstances which tend occasionally to diminish the waters of rivers, such as by cutting down the forests on the hills where they rise, and by that means diminishing the attraction for the clouds, and consequently the quantity of rain. In Kentucky, accordingly, many brooks are pointed out which now fail in summer, a thing that was unknown fifteen or twenty years ago; and in New Jersey some have entirely disappeared. On the contrary, it is found, in Kentucky, when the forests of the plain country are cut down, the rivers increase. It will aid the argument respecting the ancient rivers, to suppose, what is very probable, that the large channels of some of our present streams were formed by strong currents through straits, communicating with lakes or seas.

EDWARD.

But, with respect to the cross embankments just mentioned, I am not sure that it agrees so well with a universal deposition, which, if I understand them, the Wernerians allege; for, if the deposition was universal, then why was not the whole extent of a valley filled up? Why was it confined to its commencement or its termination?

MRS. R.

Explain it as you will, the fact of such embankments having taken place is amply proved.

EDWARD.

I think I could give a plausible explanation, by supposing these embankments to be mountain ridges, formed in some of the above-mentioned ways, which would consequently be high or low, according as they might be influenced by circumstances. I would infer that they would commonly occasion lakes in the valleys across which they happened to be thrown, by stopping the passage of the running waters that would naturally be collected there. When those waters accumulated to a greater extent than could be kept within bounds by the natural process of evaporation, they would, according to circumstances, either overflow the lowest part of the embankment, or, when it happened to be weak, would burst through with irresistible violence, and carry before them whatever opposed their current. Rivers would in both cases be formed, and the lake would often in this manner be drained, and leave a valley in its stead.

MRS. R.

Very well deduced, indeed; and I believe I can illustrate your reasoning by some appearances of greater extent, I dare say, than you can anticipate.

CHRISTINA.

I should like to have an account of some of those grand lakes breaking over their banks and sweeping magnificently down through the defiles and into the plains below them.

MRS. R.

I cannot promise this exactly; but, from what I shall tell you, you will be at no loss to fancy that such an event did occur, with some of the greatest rivers, too, in the world. The Danube, for example, rises in the mountains of Swabia, and forms, or rather runs, through the district, which is a large and circular valley, whence it escapes by a narrow rocky opening, into Bavaria. In Bavaria, it passes through many small circular valleys into Lower Austria, which is itself also a circular valley, out of which it makes its way through rocks and hills, near Presburgh, and falls into Hungary,—one of the most extensive circu-

lar valleys in Europe. At the lower extremity of Hungary it again passes through a narrow rocky channel, into Wallachia, at Orosova. We may even suppose this chain of valleys to be continued in the Black Sea, the Sea of Marmora, and the Mediterranean. Other instances of this, on the continent of Europe, are the valleys of the Elbe. Bohemia is a great circular valley, whose opening is towards Konigstein, through which the Elbe runs. Below this is another similar valley, which descends from Konigstein to Pirna, where it is nearly closed up by rocks, through which the river has cut its way to the beautiful valley of Dresden: whence, also, there is an outlet at Meissen. After passing from this into the low country, the Elbe falls into the sea, at Cuxhaven.

EDWARD.

Those are, indeed, most beautiful illustrations, and will be excellent companions to what you formerly told us of the river Ayr having formed a lake in the valley of Catrine, and afterwards worn a channel through the rocks below it.

MRS. R.

Yes: but I have a much grander instance to give you than any of these.

CHRISTINA.

The great American lakes and the Cataract of Niagara, I dare say?

MRS. R.

That would, indeed, be an instance exactly in point, were the rock of the cataract hollowed out into a channel for the St. Lawrence, and the great lakes drained of their waters and formed into valleys.

EDWARD.

Were that effected, it would be a grand and beautiful instance, though I question if it would be more so than the chain of valleys on the Danube.

MRS. R.

The instance to which I alluded being an American one, and not very far from the great lakes which we have been draining in fancy, will give us some notion what would be the consequence of destroying the magnificent cataract of Niagara. Christina, perhaps, will do me the favour to read Mr. Jefferson's eloquent description of the instance which I mean, and have here remarked.

CHRISTINA.

With much pleasure, mamma. "The passage of the Potowmac," says he, "through the Blue Mountains, is, perhaps, one of the most stupendous scenes in nature. You stand on a very high point of land; on your right comes up the Shenandoah, having ranged along the foot of the mountains an hundred miles, to seek a vent. On the left approaches the Potowmac, in quest of a passage also. At the moment of their junction, they rush together against the mountain, rend it asunder, and pass off to the sea. The first glance of this scene hurries our senses into the opinion that this earth had been erected *in process of time:* that the mountains were formed first; that the rivers began to flow afterwards; that, in this place particularly, they have been dammed up by the blue ridge of mountains, and have formed an ocean which filled the whole valley; thus, continuing to rise, they have at length broken over this spot, and have torn down the mountain from its summit to its base. The piles of rock on each hand, but particularly on the Shenandoah, exhibit the evident marks of this disrupture and avulsion from their beds, by the most powerful agents of nature,

and corroborate the impression which such monuments of war between the rivers and mountains (that must have shaken the earth itself to its centre), had created. The broken and rugged faces of the mountain on each side of the river; the tremendous rocks which are left with one end fixed to the precipice, and the other jutting out and seemingly ready to fall for want of support; the bed of the river, for several miles below, obstructed and filled with the ooze and stones carried from this mound; in short, every thing on which you cast your eye, evidently demonstrates a disrupture and breach in the mountains, and that, before this happened, what is now a fruitful vale was formerly a great lake, which might possibly have here formed a mighty cascade, or had an outlet to the ocean by the Susquehanna, where the blue ridge seems to terminate."

EDWARD.

I do admire that sublime description, and I should be delighted to visit such a scene.

MRS. R.

Here is another, very similar, in the same interesting volume, which you may also read.

CHRISTINA.

"It appears from the best accounts, that the place where the Delaware now flows through, the Kittatinny mountain, was not its original course, but that it passed through what is called the Wind Gap, a place several miles to the westward, and above a hundred feet higher than the present bed of the river. This Wind Gap is about a mile broad, and the stones in it are such as seem to have been washed for ages by waters running over them. Should this have been the case, there must have been a lake behind that mountain, and, by some uncommon swell of the waters, or by some convulsion of nature, the river must have opened its way through a different part of the mountain, and, meeting there with less obstruction, have carried away with it the opposing mounds of earth, and deluged the country below with the immense collection of waters to which this new passage gave vent. There are still remaining, and daily discovered, innumerable instances of such a deluge, on both sides of the river, after it passed the hills, and reached the champaign country beneath. On the New Jersey side, which is flatter than the Pennsylvania side,

all the country below Crosswick Hills seems in this manner to have been overflowed, to the distance of from ten to fifteen miles back from the rivers, and to have acquired a new soil, by the earth and clay brought down and mixed with the native sands."

EDWARD.

Consequently, if the great lakes, Superior, Michigan, Huron, Erie, and Ontario, were drained by deepening the channel of the St. Lawrence, we should have extensive plains like those so finely described by Jefferson, and probably Lower Canada would be overflowed by the great rush of the waters.

MRS. R.

Leaving lakes out of consideration, it is more than probable that seas themselves have, in some cases, been thus drained, at least in part, by channels produced in some of the ways which we have been supposing. Pallas has rendered it probable that there was an ancient communication, now dried up, between the Caspian, the Sea of Aral, and the Black Sea, before the opening of the Bosphorus, which enabled these seas to discharge themselves into the Mediterranean. He observed that, between the rivers Sanpa and Wolga, from

Zurzyein down to the Caspian Sea, the land slopes with considerable indentures and abrupt promontories, as if it had been an ancient coast, and continues on the same level on the east of the Wolga, in the sandy desert of Nunym, and in the more southern *steppes*, or deserts, between the Wolga and the Urul. The shells which abound in this extensive flat, exactly resemble those of the Caspian, and are different from those of the adjacent rivers. Whole deserts are covered with sand, containing an abundance of salt and salt lakes, and produce only such vegetables as grow on salt marshes; whereas the uplands that border this flat, contain a genuine black fertile soil, and no shells resembling those of the Caspian. Hence he infers, that the level of the Caspian, before it was reduced to its present limits, was ninety feet higher than at present; thus it was enabled to communicate with the Euxine, by the Sea of Asoph. In this state it must have remained from the period of the deluge, until about eighteen hundred years before our era, the most probable date of the separation of these seas, as Foster has shown in a learned memoir in the Gottingen Magazine. Dr. Kirwan infers that, when the Euxine thus obtained a communication with the ocean,

through the Mediterranean, its level would gradually subside, and the canals which joined it with the Caspian, and the Caspian with the Aral, were dried up, and the great salt deserts on their shores produced.

EDWARD.

All which, I perceive, is part of the same conjecture which, by means of an earthquake, opened a communication between the Mediterranean and the ocean.

MRS. R.

It is so: and on similar principles it is affirmed, that the Baltic was anciently much more extended, and covered the immense plains of southern Russia, from Petersburgh to Pultowa, which are still in many places covered with sand, pebbles, and shells, and in others full of extensive morasses,—not salt, indeed; but that is no argument against the theory; for the waters of the Baltic are only in a slight degree salt, and are said to have been entirely fresh before it burst a passage into the German Sea, and thus communicated with the ocean.

EDWARD.

How plausible and probable soever this may appear, I should hesitate a good deal before I

could admit it, without more satisfactory proof than the shells, the marshes, and the freshness of the water.

CHRISTINA.

Geology, I find, is an excellent exercise for the imagination. It is even superior, perhaps, to astronomy itself in this respect.

MRS. R.

In some measure it is; but it sometimes also, as you will allow, lays the fancy prostrate and confounded, like the opium-eater in his dreams, among marshes, "slimy things, and Nilotic mud."

EDWARD.

Marshes are certainly not a subject for a fine poetical description; but yet, as we have just seen, they may occasionally aid poetical philosophy, as, I think, I may well call the account of the Baltic just mentioned.

MRS. R.

I can tell you something less poetical, but, perhaps, more true, than that concerning marshes and their origin, of which the Irish bogs are a singular example.

EDWARD.

I have heard the Bog of Allen mentioned as a very extensive one.

MRS. R.

You are not, however, to suppose that the tract called the Bog of Allen is a single marsh; for the name is given to the whole belt or chain of bogs situated on the east of the river Shannon. Many of the several divisions of this are contained in basins, distinct and separated by high ridges of dry country, the edges of which are abrupt banks of limestone gravel, sometimes consisting of shingles perfectly rounded, as if formed on a beach.

EDWARD.

This seems to indicate the previous existence of a sea or lake.

MRS. R.

So it may naturally be supposed; and, with respect to the gravel-bank called the Ridge of Maryborough, I think there can be little doubt that this was its origin, as it is seven miles in length, fifteen feet high, and broad enough for

four horsemen abreast, and very irregular, like the sand-banks on the sea-shore.

EDWARD.

I should think, then, that the bogs must have originated from the sea.

MRS. R.

Notwithstanding that circumstance, which may be thought to favour such an opinion, nobody has supposed the bogs to have been produced either by the sea or by lakes. Some conjecture that, in this boggy part of Ireland, extensive forests formerly existed; and that the outer trees of these forests, which were the strongest, being felled, the interior trees were blown down, and formed, in decaying, the origin of bogs. But Mr. Griffith, in his report on a part of the Bog of Allen, lying in the north-west part of the county of Kildare, denies the probability of the opinion above stated, and says that, in all the clay-lands in this part of the country, wherever water is suffered to remain for any length of time, an incipient formation of bog is the invariable consequence: this formation takes place by the growth of bog-moss, and other aquatic mosses and plants;

and of the remains of these plants, the moss of the bog in the above district is composed. He adds, that, in some instances, as at Hatfield, in Yorkshire, bogs may have been formed by trees falling down and causing an interruption in the flow of waters, but that those that he describes have accumulated entirely from the growth of the mosses in stagnant water; for that, in the body of these bogs, trees or branches of trees are rarely found, being generally met with only on the edge of the bog. Like the moss on the brick wall, the bog-moss decays at the root, and forms a soil for the growth of fresh mosses and bog-plants, and in this way peat-bogs are always growing deeper every year.

EDWARD.

This is, indeed, a very probable account, though it gives no explanation of the gravel-banks.

MRS. R.

What confirms it strongly, is the collateral account given by De Lac, of the origin of the marshes or bogs of Holland, with this remarkable circumstance in addition, that the boggy ground is formed periodically, and is covered from time to

time with the mud, sand, and sludge of rivers, forming alternate strata of alluvia* and bog.

EDWARD.

This process, however, I should imagine to be rather slow, and many centuries must elapse before many such alterations are effected.

MRS. R.

On the contrary, the formation of bog is said to go on with great rapidity; but, no sooner does it acquire any considerable volume, than it slips forward, unless prevented by artificial means, and the rivers inundate it, cover it with sand and sludge, till they bank themselves out again by their own depositions, and the bog process again commences above the alluvia thus formed.

EDWARD.

In this way, I should imagine that, unless the channels of the rivers were gradually elevated, the alternating strata of bog and alluvia would soon be placed above the reach of inundation.

---

* See Conversation the Sixth.

MRS. R.

Sometimes the channels of rivers are raised by the deposition of sand and mud, but then, you must perceive, the river cannot run there any longer, but must seek a new channel, as is frequently the case with such rivers; as happened to the Jellinghy river, in Bengal, the outlet of which into the Ganges was moved nearly a mile within a few years.

EDWARD.

If I understand this process correctly, it always requires stagnant water to form a marsh; and if, by any accident, sea-water were rendered stagnant, a salt marsh would in process of time be the result.

MRS. R.

That would be in proportion to the depth of the water, I conceive; for the water itself could not form the marsh, unless aquatic plants grew in abundance; and in very deep water these would not thrive. It is in shallow ponds and lagoons that the process is most successful; and it is in this way that the extensive swamps and savannahs of America and Asia appear to have originated, as Humboldt, Barrow, and Turner describe.

EDWARD.

Still, I am by no means satisfied with respect to the gravel-banks which you mentioned as inclosing some of the Irish bogs.

MRS. R.

I think there can be no doubt that these have been formed either by lakes or rivers, but probably long before the bog process commenced. A good illustration of this is given by the celebrated Saussure, who says, that the back-waters occasioned by the entrance of the Rhone into the Lake of Geneva, aided by westerly winds, has thrown up so much sand to the east of the entrance of the river, that, within the period of history, a village, formerly situated on the borders of the lake, has been separated from it by an interval of half a league: and, within the space of fifty years, an eye-witness, on whose fidelity he could rely, told him, that he had measured an extent of new ground half a league in length, and more than forty paces in breadth. And it is observed generally, by Saussure, that all the lakes he had ever visited are filling on that side whence they have their source; namely, in con-

sequence of the deposition of the sand of the rivers that enter them from the mountains. Thus, the Lake of Nantua, between Lyons and Geneva, he says, is evidently in the progress of filling up; and the Lake of Thun forms, also, by its contractions, large alluvial plains on its borders: and between the Lakes of Brientz and Thun is a plain of a league in length, evidently of alluvial origin. Pallas observes, that the Lake Baikal also, in the south-east part of Siberia (which lake, compared with many others, is an inland sea), was formerly much more extensive than it is now.

EDWARD.

This will, indeed, afford an excellent explanation of the Irish gravel-banks.

MRS. R.

As to the filling-up of lakes, by far the most remarkable instance of this natural process is given by Humboldt, in his account of Mexico. The valley in which the city of Mexico is situated, though more than five thousand feet above the level of the sea, is literally encircled by a chain of mountains; and it seems evident that this valley is the bottom of a lake which once was

spread over it, and of which the five comparatively small lakes, now occupying portions of it, some of fresh and some of salt water, are the remaining. About one tenth of the area of the valley of Mexico, that is about twenty-four square leagues, is occupied by four principal lakes. In October, 1520, Cortez describes two great lakes as existing in this valley, one of salt water, the other of fresh water. It was in the salt lake that Tenochtitillan, the old city of the valley, stood; and it was surrounded on all sides by water, having causeways leading to the main land. At present, the centre of the city of Mexico, placed on the site of Tenochtitillan, is four thousand yards from the others, so that the present city is placed entirely on *terra firma,* between the salt-water and the fresh-water lake; and, from geological observations, it is probable that these lakes had begun to diminish long before the arrival of the Spaniards in the sixteenth century.

EDWARD.

I suppose the process of filling-up is similar to what takes place in Holland, Ireland, and the Swiss lakes.

MRS. R.

The process is somewhat modified by the cli-

mate. In dry summers, so small a quantity of water comes into the lakes, and there is always so great a degree of evaporation going on at that elevation, that the gradual lessening of the lakes is easily accounted for; and it evidently appears that the shallower parts, being gradually exposed, in consequence of evaporation, become marshy grounds, which, being first drained by artificial canals, are subsequently cultivated. The lessening of the lakes became much more rapid after the conquest; for, the Spaniards every where destroying the trees, the shade of which had retarded evaporation from the surface of the soil, the retained moisture thus passed by infiltration into the lake. Artificial drainage has stopped the overflowing of the northern lakes of the valley, into the southern; with respect to which inundation this remarkable fact is stated, that they periodically return every twenty-five years. The city of Mexico is scarcely four feet above the level of the neighbouring lake, and, as the mountain streams are constantly elevating the bed of the lake by the sand they bring down, the level of its surface is constantly coming nearer the level of Mexico; and, consequently, the danger of inundation is increasing. Humboldt observes,

that, with the view of obviating a similar danger, the Venetians have turned away from their lakes the Brenta and several other rivers which deposit sand in theirs. It appears from this that the valley of Mexico was, probably, once entirely a lake.

CHRISTINA.

All this, however, is nothing to the valley of the Susquehannah, as described by Jefferson.

MRS. R.

But I can give you a much prettier instance than either. According to Major Rennell, the country of Cashmere, which has been called the Paradise of the Hindoos, the garden of perpetual spring, is an elevated valley, surrounded by steep mountains: the soil is of the moistest nature, and of vast depths, and composed of the mud dsposited by the River Chelum, which originally occupied the whole valley, in the form of a lake, until it opened itself a passage through the mountains. Major Rennell adds, that, although the foregoing account has no living testimony to support it, yet history and tradition, and, what is yet stranger, appearances, have impressed a conviction of its truth on the minds of

all those who have visited the scene, and contemplated the different parts of it. At the present day, many small lakes are spread over the valley of Cashmere, some of which contain floating islands. He also says he is so far from doubting the traditions respecting the existence of the lake that covered Cashmere, that appearances alone would serve to convince him, without either the traditions or the history. It is a mere natural effect; and such must be the economy of nature in every case where the waters of a river are inclosed, in any part of their course, by elevated lands.

EDWARD.

When so many facts occur, we must, undoubtedly, yield assent to the conclusions.

MRS. R.

Major Rennell gives a much more distinct account of the progress of those events, than we have hitherto had. "The first consequence," he says, "of the stoppage of the waters, is, of course, the conversion of the inclosed land into a lake; and, if this happens near the fountain of the river, and the ground is solid, it is likely to remain a lake for ever, the river not having force enough,

in its infant state, to work itself a passage through the mountains. Hence it is, that more lakes are found near the source of rivers than in the lower parts of their course. If the river be enclosed after it has gained a great accession of water, and, of course, strength, it will, indeed, at first, form a lake, as before; but, in time, the place at which it runs over will be gradually fretted away, as in the case of the Chelum, above mentioned.

EDWARD.

This is, indeed, most clear and plausible.

MRS. R.

And it will apply exactly to all the instances which we have already considered, as well as to others of a similar kind. The Euphrates, for example, in like manner, opens itself a passage through Mount Taurus, and the Ganges through the Himmaleh mountains; and, even though the base of the mountains be of the finest texture, it will give way to the incessant frictions through a course of ages. The valley of Nepaul, separated from Tibet by a point of the Himmaleh mountains, is about four thousand feet above the level of the sea; and Colonel Kirkpatrick thinks that all the

arguments used by Major Rennell, to show that Cashmere was once a lake, apply with equal force to the Valley of Nepaul.

EDWARD.

I am now quite convinced of the truth of these beautiful speculations.

CONVERSATION TENTH.

ORDER OF ROCKS, WITH THE ORIGIN OF COAL AND THE DIFFUSION OF GRAVEL AND SAND IN THE SEA.

EDWARD.

SINCE our last lesson, I have been considering the nature of the depositions we have been discussing—the beds of gravel, the strata of bogs and marshes, the tracts of sand in the deserts, and the soil which so generally covers the earth; and I cannot conceive how these, even with the aid of Dr. Hutton's great central fire, could be melted and converted into granite, slate, and other rocks.

MRS. R.

Your difficulty upon this point is natural enough, and it has puzzled the theorists not a little to explain it; but, if you wave the objection and listen

to their own statements, you will find them to be very plausible.

EDWARD.

I find, indeed, that this is the best way of understanding any theory, though I cannot refrain from mentioning such objections as suggest themselves to me.

MRS. R.

Dr. Hutton seems to have taken the fundamental idea of his theory, respecting the origin of rocks, from the fact with which we began our geological lessons—I mean, the existence of shells in rocks: from which he justly inferred that the shells had existed before the rocks; or, at least, before they were consolidated or hardened. This cannot be denied, I think; though I am by no means certain that it authorizes the conclusion of *all* rocks being formed of materials derived from the destruction of rocks, or other substances, previously existing.*

EDWARD.

The fact of the shells seems to be too confined for so general a conclusion.

---

* Hutton's Theory, vol. I. page 20; and Playfair's Illustrations, page 5.

MRS. R.

Yet it may be worth while to consider how they manage their proofs. You must understand, then, that it is chiefly, if not exclusively, in marble, limestone, and chalk rocks, that shells are found embedded; and we have already seen one undeniable instance of this class of rocks nearly formed by the coral polypi of the tropics. There are other rocks of the same class, composed of fragments, which have, apparently, been detached from rocks previously existing, and are now formed into solid rock by means of a cement of a substance similar to themselves. Hence it is concluded, that at least all calcareous rocks, that is, such as contain lime, have been derived either from the destruction or disolution of ancient limestone rocks, or from coral reefs, banks of sea-shells, and other marine remains.

EDWARD.

If all the facts were as clear as these, the theory would be almost perfect.

MRS. R.

The conclusions of the theorists, even here, go

rather farther than the facts will bear; for, having thus discovered the origin of one or two calcareous rocks—the coral reefs, for example, they say that it is unnecessary, and must be unphilosophical, to look for any other origin, even of such calcareous strata as exhibit no traces of shells of fragments of former rocks.

EDWARD.

I should certainly not be inclined to admit this.

MRS R.

Particularly when you consider that the beautiful Carrara marble, which is white, crystalline, and translucent, and does not contain a trace of corals, shells, or fragments of previous rocks, would be invalued in the inference. Nobody, indeed, who looks at what Geologists calls primitive or primary marble, of which the Carrara is a good example, could suppose, for a moment, that it could, in any manner, be formed of fragments of ancient rocks which have been first destroyed, and subsequently agglutinated or cemented together, much less from coral, or marine shells.

EDWARD.

As we are not pledged to be disciples of the

theory, perhaps it will be the best way to admit only that part of the proposition which is proved, and cut off the Carrara marble and similar rocks from the conclusion.

MRS. R.

We shall have to do the same, I suppose, in the case of other rocks, that are not of the calcareous class.

EDWARD.

The theorists will, in such cases, I suppose, be deprived of the assistance of corals and shells.

MRS. R.

Yes, but they have still their grand argument of the fragments; which, in many cases, is not less probable than the shells and corals.

EDWARD.

In the case of the conglomerate, or breccia, such as the specimen in our cabinet, I think they will find their task easy enough; but I cannot imagine how they will explain the origin of granite, slate, serpentine, and many other rocks, which are so very different in structure from the conglomerate.

MRS. R.

Dr. Hutton was very hard pushed upon this point, by some of his opponents, to whom he replied that, if a single water-worn stone, or any animal or vegetable petrifaction, were found in granite or any of the rocks of the same class, it would be quite sufficient to authorize his inference. With this view it was that gravel was said to have been found in granite and slate rocks; but the circumstance is very doubtful; and, even were it true, a single instance would scarcely support so wide a conclusion.

EDWARD.

I should like, however, to know some of the instances referred to.

MRS. R.

One of these is granular felspar, described by Saussure as occurring on the ascent of Mount St. Gothard; but he himself denies the inference which has been drawn from his description. A number of other instances, equally equivocal and unsatisfactory, are said to occur between Ardnamurchan and Genely, in Scotland—at Balachulish Ferry, and on the shore at Cullen. The first

is said to exhibit granitic sandstone, and the second granular quartz; but, in all probability, the first is small grained granite, and quartz often assumes a granular structure: though none of these instances prove that such grainlike appearances are the disintegrated particles of ancient rocks, more than the limestone of the Velino at Tivoli, which I described to you the other day, would prove the same.

EDWARD.

But you mentioned animal and vegetable petrifactions, and perhaps these might make up for the want of evidence from the occurrence of water-worn stones or gravel.

MRS. R.

Here Dr. Hutton does not fare much better than in the case of the gravel; for, in the primitive, or, as he calls them, primary rocks, none of these are unequivocally proved to be found, though several doubtful instances are given.

EDWARD.

If none of these proofs are better than those brought from the gravel, they are not much to be depended on.

MRS. R.

The chief proof alledged is taken from coal; and Dr. Hutton has, in consequence, composed a very pretty romance respecting the origin of coal.

CHRISTINA.

I am glad of that, mamma, for I was getting tired of the gravel and granite.

MRS. R.

Dr. Hutton is quite right, I think, in tracing coal to a vegetable origin, as I shall afterwards try to prove to you at more length; but I think he is extremely fanciful and wild in his history of the manner of its formation.

EDWARD.

I confess that it would require very strong proof indeed, to convince me that all coal is originally derived from vegetables.

MRS. R.

You would require stronger still, for Dr. Hutton's theory of its production. The smoke, he says, which is carried up from our fires, mingles

with the moisture of the air, and is again, by rains and dews, carried down to the earth, from which it is washed into the sea by streams and rivers. The smoke, having thus reached the sea, falls to the bottom, and forms the beds of coal which are to supply fuel to the new continents, when they re-emerge from the bosom of the ocean.*

CHRISTINA.

This is, indeed, a romance, but I should scarcely call it a pretty one.

MRS. R.

He would have been nearer the truth, I think, if he had considered that the smoke diffused in the atmosphere is again brought down to the earth by showers, though not for the purpose of being carried into the sea, by rivers, to form coal for a future world, but for the supply of nourishment to growing plants. The quantity of smoke, indeed, which goes into the sea, must almost be limited to the precipitation of it by rains which fall there; and this, in all probability, instead of being deposited at the bottom, will float and be again exhaled, or ex-

* See Hutton's Theory, vol. I. page 577.

pended in the nourishment of sea-weed and other marine productions.

EDWARD.

This is, undoubtedly, a more probable account of the matter; but, even granting to Dr. Hutton that coal was thus produced, or that it originated from vegetables in any other manner, I cannot perceive how it will aid him in accounting for the origin of granite.

MRS. R.

He reasons thus: if coal, being derived from the vegetable materials of a former world, is found connected or alternating with granite, gneiss, slate, and other primary rocks, then must we conclude that those rocks, also, were derived from the materials of former rocks. Accordingly, he alleges that coal is found thus connected with primary rocks in Dauphiny; but, on turning to the description of this coal in the *Journal des Mines,* I find that it overlays the rocks, and is, consequently, newer; while those rocks themselves upon which the coal rests are not primary, but secondary.

EDWARD.

We must therefore give up, I suppose, all those

untenable conclusions; at least, till they are better supported.

MRS. R.

Since it must be so, let us try whether the Wernerians can give any better solution of the question; and I rather think they must be peculiarly strong here, if I may judge from the circumstance of the Huttonians laying aside argument, and resorting to abuse; for I never have observed any body do so when there were good reasons for an opinion.

EDWARD.

Abuse and vituperation would never, I should imagine, aid a cause; and I wonder Dr. Hutton did not know better.

MRS. R.

I did not mean Dr. Hutton: philosophers have generally sufficient respect for themselves to prevent this. It is an anonymous antagonist who accuses the venerable and modest Werner of "the presumptuous task of carrying his reasonings beyond the boundaries of nature, and of unfolding the properties of the chaotic fluid with as much minuteness of detail as if he were describing the circumstances of a chemical deposit which he had

actually witnessed;" while he is, "in the very outset of his rash course, found floundering in the muddy depositions of a chaotic ocean, which he has unwisely created for his own entanglement,—by whose treacherous quicksands he is constantly betrayed, and from the dye of whose mud not all the solutions in which he afterwards immerses the world can effectually purify him."

EDWARD.

I think the Huttonian who would use such language might have it much more appropriately turned against himself.

MRS. R.

The truth is, that Werner does not make the smallest pretension to divine how the materials of rocks came to be dissolved in the primeval ocean, but only endeavours to prove, from the present appearances of rocks, that they have been so dissolved, and are not, as Dr. Hutton alleged, derived from rocks previously existing.

EDWARD.

The latter opinion is probable, I think, were it from no other circumstance than the weakness of Dr. Hutton's proofs.

MRS R.

Werner argues plausibly, that, if granite, gneiss, and primitive slate had been derived from previous rocks, *every part* of them, and not some rare or solitary appearance, would bear undoubted testimony of this origin, as we see is the case with breccia or conglomerate rocks, and with shell limestone; but the facts are not found to be so, for no trace of ancient remains, either petrous or organic, has ever been discovered in those rocks.

EDWARD.

This seems to be quite conclusive.

MRS. R.

The inference is farther supported by considering the improbable length of time which it would necessarily require to wear away, from similar masses and strata, all the materials of which primitive rocks are composed; and it is all but proved, from the fact of its being in many cases impracticable either to dissolve them in water or fuse them by means of heat, as we formerly remarked.

EDWARD.

Both of these circumstances are in favour of Werner and against Dr. Hutton; for, though their insolubility now does not prove that they have not formerly been dissolved,—as they agree in this with the known properties of Puzzolanum or Roman cement, and the incrustations on the inside of tea-kettles,—yet it also proves that now they cannot be dissolved or fused, as Dr. Hutton supposes.

CHRISTINA.

This argument, Edward, is too nice for my poor apprehension.

MRS. R.

It is ingenious, notwithstanding, and plausible, if you will take the trouble to examine it; and it may be aided by the presumptive evidence from indirect proof, that, if such ancient rocks had ever had any existence at any period, however remote, it is likely that there would have been discovered some whole rocks of them still undestroyed; but nothing to countenance this idea has ever occurred to any Geologist.

EDWARD.

But suppose we should grant Dr. Hutton all those materials of destroyed rocks, and suppose they were diffused over the bottom of the sea, ready to be melted by the great central fire, I cannot conceive how he explains their separation into distinct rocks, such as granite in one place, and sandstone or chalk in another; for the worn materials would naturally, I suppose, be in one mingled mass, like breccia.

MRS. R.

Dr. Hutton explains the process thus:—The worn materials of rocks are carried into the sea by rivers, and spread over its channel by the action of currents and tides; but, as this is all mechanical, the materials which are lightest will travel farthest, while those which are heavy will be carried to the least distance. These weightier materials again are prevented from accumulating on the coast, by being further worn down and carried off by tides and currents.

CHRISTINA.

But, mamma, you showed us before, that those

materials did not travel over the channel of the sea, but formed sand-banks on the shore.

MRS. R.

True, my dear; and this being very commonly the case, was strongly urged by Dr. Kirwan and others against the theory.

EDWARD.

Yet the objection does not appear to me to disprove the opinion, for I think I could explain it.

MRS. R.

You may do so readily, if you consider that the channel of the sea is usually found to slope away from the shore, and become deeper and deeper.

EDWARD.

Yes: and, as this slope is composed of sand and gravel, it must be influenced by the water soaking into the mass, and by the continual agitation of the tides above it; and in this manner it must yield on the side of the least resistance, and be slowly and gradually diffused over the bed of the sea. Even the coarser gravel will be extended in the same manner; for, as it rests on an inclined

plane, that which lies on the surface will be sensibly raised by the action of the waves, whose return will carry it back again; and, as its weight will then increase its motion, it will be carried back farther than the advancing waves carried it forward, and it will thus travel to a great distance from shore.

CHRISTINA.

I am sorry I cannot clearly follow this account, though I think it very pretty, so far as I understand it.

MRS. R.

You cannot expect, my dear, to comprehend a complicated subject all at once, without trouble; and Edward's mathematics give him a great advantage in such arguments.

EDWARD.

I think I can explain, on the same principles, how gravel and sand are *thrown up* on the shore, instead of being diffused; for, when it so happens that the slope is not steep or much inclined, the advancing wave will have more force than the returning one, and carry the sand or gravel towards the shore.

MRS. R.

This, however, will not hold at great depths, where the weight of the water above the gravel and sand will move it forwards, even on the most gentle slope; and none of your arguments will apply to vegetable or animal substances floating in the water, nor to mud diffused through it.

EDWARD.

I did not advert to those exceptions.

MRS. R.

Neither did Dr. Kirwan, when he asserted that none of the gravel, sand, or mud carried by rivers into the sea, are conveyed to any distance, but are either deposited at their mouths, or thrown up by currents and tides; for, he argues, the tide of flood being always more impetuous and forcible than the tide of ebb, the advancing waves being pressed forwards by the countless number behind them, while the receding waves are pressed backwards by a far smaller number, every thing cast into the sea will eventually be carried to the shore.

EDWARD.

This reasoning will not apply to gravel and sand, but only to things which float.

MRS. R.

Kirwan, besides, has forgotten, or was not aware of the fact, that earthy matters are often carried to great distances, as is seen in the colour of river-water after heavy rains; and from this cause, Don Ulloa tells us, the Rio de la Plata colours the sea to the distance of many leagues from the shore. It was formerly mentioned that the great river Hoanho was found, by experiment, to carry along with its current about two millions of solid feet of mud in the hour, which, of course, must be gradually deposited in the Yellow Sea, and thence diffused by tides and currents over the bed of the Pacific Ocean. Accordingly, it is found, that ships navigating this sea draw up mud which is visible to a considerable distance in their wake; and La Perouse obtained soundings from twenty-two to forty-five fathoms, at fifty leagues from land.

EDWARD.

Those facts are better than the best speculative arguments.

CHRISTINA.

Yet you will allow that this part is not so interesting as the beautiful accounts we lately had of rivers and lakes.

MRS. R.

But what would you say, my dear, were I to tell you of a river a thousand miles broad, traversing the whole globe of the earth in its course?

CHRISTINA.

I should say, that it is either a romance of some Arabian tale, or of some of your geological theorists; for no such river, I am sure, exists.

MRS. R.

On land, I grant, there is not; but the river I mean is an *ocean-river,* if the term may be allowed.

CHRISTINA.

That is still more incredible and unaccountable.

MRS. R.

It is, however, a fact, and not a fancy, as I shall show you.

EDWARD.

If that can be satisfactorily proved, I can perceive how it may be turned to good account in explaining many of the subjects which we have been discussing, not only in transporting sand and gravel, but in hollowing out valleys, undermining mountains, and many others.

MRS. R.

This is precisely the application for which I mentioned those magnificent ocean-rivers or currents, which seem to run with as much regularity in the sea as rivers do upon land. We are chiefly indebted to the researches of Major Rennel for collecting the scattered observations which had been made on these grand currents, and to Mr. Playfair for applying them to Geology.

EDWARD.

I do not recollect seeing them laid down on any map.

MRS. R.

Not in the common geographical maps; but

they are marked by arrows in sea-charts. The principle is this: more water is evaporated by the great heats of the equator, and carried up into the air, than is restored by the tropical rains and rivers; the currents of warm air, going towards the poles, carry this evaporated air, along with them, and, when it comes into colder latitudes, it falls in rains, giving a greater supply of water to these regions than they lose by evaporations. This superabundant water cannot, in consequence of the earth's figure and motion, remain where it falls, but streams back to the equator, as is proved by the annual emigration of the polar ice-bergs towards the tropics.

I shall begin to trace the great system of currents from the west coast of America across the Pacific Ocean. Of this current we as yet know little more than that it exists. One branch of it strikes on the south of New Holland, running through Bass's Straits and round South Cape; and another branch of it runs among the islands of the Archipelago, on the north of New Holland. On entering the Indian Ocean and meeting the south polar current, it runs through the Gulf of Bengal, round Cape Comorin, and over to Africa, acquiring great velocity in its passage. From the Straits of Babelmandel, it keeps always a south-

west direction, till it doubles the Cape of Good Hope, when it turns to the north-west, following the line of the coast. On approaching the Equator, it sets nearly east. When in the latitude of 3° North, it meets with another current, which has run southerly along the west coast of Africa, uniting with this current and crossing the Atlantic Ocean, nearly in the direction of W. S. W.; on reaching the Brazils, it diverges, at Cape St. Augustine, into two streams,—one running south-west, parallel to the coast, till it doubles Cape Horn, where it meets the south polar currents, which run among the islands at Cape Horn. The other part of the great Atlantic current takes its departure from Cape St. Roeyne, and proceeds in a northerly direction through the Gulf of Glandin, along the shores of the United States, where it is called the Gulf Stream, to Newfoundland; and here it is backed by the North Polar current, takes an easterly course across the Atlantic, again coming over on the coast of Norway and the British Isles, and turning thence to the south, through the Bay of Biscay, and along the coasts of Africa and Spain, to meet the great southern current, in the latitude of 3° North. The breadth of the African branch of this magnificent ocean-river is from a

hundred and fifty to a thousand miles, and at the Cape of Good Hope it runs at the rate of about two miles an hour; at the equator it runs three miles and a half an hour; and the gulf-stream, on issuing from the Straits of Bohemia, goes four miles an hour. In the latitude of 30° the water is found to be ten degrees warmer than the air; and, before the principal cause of the current was known, it sometimes gave rise to apprehensions that it would melt the pitch of vessels, and occasion their loss, from a supposition that it was connected with some volcano.

CHRISTINA.

This is, indeed, grand, magnificent, and interesting.

EDWARD.

And the account of the cause is no less so than the detail.

MRS. R.

When taken in conjunction, indeed, with what we know of a similar system of counter currents, which have often been discovered running at great depths, it must be inferred that the materials on the bed of the sea will, in consequence, suffer very considerable changes.

EDWARD.

And, if such currents existed, as from the causes mentioned they must have done, in the primeval ocean, the mountains and valleys would be in the same way much modified before the appearance of dry land.

MRS. R.

At the great deluge of Noah, likewise, the same currents would be powerful agents, and would probably produce many of the gravel-beds that cannot be otherwise accounted for. There is also another much-contested subject of Geology, which those currents may help to explain,—I mean the great rounded blocks of granite and other stones, which are often found in the fields, far from any rock whence they could have been detached.

EDWARD.

You alluded to these stones before, if I recollect, under the name of *bowlders*.

MRS. R.

Yes: they are very important in geological speculations. De Luc supposed them to have

been blown up from below by explosions of gas; others suppose that they are the remains of rocks that have been worn away; and others, that they have been carried to their present situation by tremendous mountain torrents, called *debacles*, or have been floated on ice-islands from the polar regions.

EDWARD.

There has, at least, been no want of theory upon the subject.

MRS. R.

Perhaps several causes co-operated in transporting the stones, but none more probably than the great currents of the ocean and the violent mountain torrents. No ordinary cause could transport such immense blocks, which are chiefly granite and other primitive rocks. I have seen one of several tons' weight on the shore of the great Cumbra, in the Firth of Clyde, and yet no granite rock is nearer to it than the Arran Mountains, across an arm of the sea many miles wide; I have seen another very large one on the declivity of the Cathkin Hills, near Glasgow, which must be thirty or forty miles from any granite rock.

EDWARD.

These facts are most singular, and are scarcely accountable, I think, even from the action of the strongest current or most violent torrent.

MRS. R.

The instances given by Saussure, De Luc, Von Buch, and others, are even more extraordinary. Mr. Greenough, for example, describes huge blocks of granite scattered over Cheshire, Shropshire, and Staffordshire, corresponding in appearance with the rocks of Westmoreland and Cumberland so exactly, that the exact spots from which they have been detached, as well as their precise route, may be traced, and the instances also of granite masses in Cumberland corresponding with the rocks of Criffel, in Dumfrieshire. Von Buch and Hansmann have in the same way traced the huge granite blocks in the north of Germany, across the Baltic Sea, to their birthplace in Norway and Finland. Saussure and Von Buch also traced the granite blocks which are so numerous on the limestone declivities of Mount Jura, to their parent rocks on Mount Blanc, and other Alpine mountains many leagues

distant. They could even discover, in many instances, the openings among the mountains through which the blocks had travelled.

EDWARD.

The largest rivers could not, it is obvious, remove such large blocks of stone to so great distances.

MRS. R.

No: and not even much smaller ones. Saussure says, the plain of Crau, occupying a triangular area of nearly twenty square leagues, is covered with bowlders, which, by some, are supposed to have been brought thither by the Rhone, by others, by the Durance. Nearly seven-eighths of these bowlders are very close-grained gritstone, usually of a white colour, though sometimes yellow or red, their size near the surface being commonly that of a man's head; from which circumstance Saussure is decidedly against the notion, that they have been brought down either by the Durance or Rhone, for these rivers now bring down only sand, which covers and fills up the intervals of these bowlders. He thinks, therefore, that, when the waters of the ocean abandoned our present continents, to retire

towards the supposed gulfs which they now occupy, a violent current, hemmed in to the west by the mountains of Dauphiny and Provence, carried down fragments from all those mountains. As a proof of this, also, he discovered the marks of a water-course that has corroded the rocks in narrow passes, much above the level of any river in the neighbourhood.

EDWARD.

This forms an admirable illustration of our former discussions on the formation of valleys.

MRS. R.

And still more, I think, of the formation of gravel; for if rivers, in their ordinary course, cannot transport large stones, they may wear them down. That they do not carry them far, is finely illustrated by Bowles, in his Travels in Spain. I have marked the passage for Christina to read.

CHRISTINA.

"From the singularity of their appearance," he says, "there are few pebbles which it would be so easy to recognise, as those in the bed of the river Glenares, near St. Fernandez. If they ever

moved at all, they ought, in the course of ages, to have found their way into the Tagus, a little way off, but there is not one of them to be seen there. At Sucedon, the Tagus is full of limestone pebbles, but lower down, at Aranjuez, there are none. Nobody has ever seen granite pebbles, large or small, in the Ebro, nor blue stones veined with white; yet the Cinca, before it joins the Ebro, abounds in those. The river Gaudiana, in different parts of its course, flows over pebbles similar to those found on the adjacent hills; but those which occur half a league up the stream never mix with those which occur half a league lower down; and, at Badajos, stones of this kind, being no longer found in the cliffs, are no longer found in the river.

"Near the Rente du Rhone, you cross the river of the Valoraine, which is full of pebbles, because the country it flows through is full of them.—In one place this river tumbles into a kind of cavern; now, if pebbles were carried down by rivers, this cavern ought to contain them in abundance, but it does not contain one. On my way to Geneva, I threw some stones, which I had marked so that I might know them again, into this river, just above its fall into the cavern, and there I found them

on my return; they had not advanced an inch during my absence."

EDWARD.

Yet, if this be the case, what are we to make of the circumstances you formerly mentioned, as seen at Bello Mill?

MRS. R.

I confess I do not well know,—and these circumstances are not singular or peculiar. Ehrhant, speaking of gravel in the Tyrol, says, "These stones increase in bulk from Memingen to nearly the Alps, till they get to be three or four feet in diameter; in the opposite direction they gradually decrease to the size of coarse sand. We may collect from Guetland, that a similar gradation is found in the gravel which covers the plains of Poland, from the Carpathian mountains to the Baltic." It is true that blocks of very different sizes are sometimes found together, both on hills and plains; that in some places the small pieces are in abundance, though there are few blocks, and that in others the blocks are in abundance, though there are few of the smaller pieces. I would refer these seeming irregularities to some

local cause, as similar irregularities take place on a smaller scale, in the worn materials produced on the sea-shore by the waves, and by inland torrents.

EDWARD.

But still the question as to the orderly arrangement of beds, either of stone or gravel, is left unanswered.

MRS. R.

Werner, of course, explains this question by referring to the varied effects, sometimes, of crystallization, which does not follow the laws of gravity; and sometimes to mechanical deposits, which do: but the subject has been left much in the dark. The latest Geologists have paid great attention to the facts of the order in which rocks are found in nature, or rather the order in which they can best describe them, and I have drawn out for you some short tables of the most recent of these. The first which I shall show you is—

DR. MACCULLOCH'S CLASSIFICATION OF ROCKS.

PRIMARY CLASS.

Unstratified.

Granite.

Stratified.

Gneiss	Red Sandstone
Micaceous Schist	Argillaceous Schist
Chlorite Schist	Diallage Rock
Talcose Schist	Limestone
Hornblende Schist	Serpentine
Actinolite Schist	Compact Felspar
Quartz Rock	

SECONDARY CLASS.

Stratified.

Lowest (Red) Sandstone	Limestone
Superior Sandstone	Shale

Unstratified.

Overlying (and Venous) Rocks	Pitchstone

OCCASIONAL ROCKS.

Jasper	Gypsum
Silicious Schist	Conglomerate Rocks
Chert	Veinstones

APPENDIX.

Volcanic Rocks	Alluvia
Clay, Marle, Sand	Lignite
Coal	Peat

EDWARD.

I should question the propriety of calling sand a rock, though I know it is all produced from the wearing-down of rocks and stones.

MRS. R.

There are many more objections than this to Macculloch's classification: his appendix is clumsy; his terms "quartz *rock*," "diallage *rock*," and "*compact* felspar," are redundant; his term "schist," for *slate*, is pedantic; his *stratified* and *unstratified* rocks are not always so; and his *occasional* rocks are some primitive and some secondary. These objections, and several others, will not apply to an improvement proposed by one of his reviewers* in the following

NEW CLASSIFICATION OF ROCKS AND STRATA.

Primary Class.

Granite	Diallage
a. Stratified	*a.* Stratified
b. Unstratified	*b.* Unstratified
c. Venous	Marble

* Eclectic Review, vol. xv., New Series, page 438.

Gneiss
Mica Slate
Chlorite Slate
Talkose Slate
Hornblende Slate
Actinalite Slate
Quartz
Red Sandstone
Clay Slate
Serpentine
 a. Stratified
 b. Unstratified
Felspar
Jasper
Flinty Slate
Chert
Gypsum
Breccia

Secondary Class.

Consolidated.

Sandstone
 a. Lowest Red
 b. Superior
Limestone
Shale
Trap
 a. Overlying
 b. Venous
Pitchstone
Jasper
Flinty Slate
Chert
Gypsum
Veinstones
Breccia
Volcanic Rocks
Coral and Fossil Wood

Unconsolidated.

Volcanic Products
Clay
Marle
Sand
Gravel
Bowlder-Stones
Loam
Peat
Shells.

EDWARD.

I can understand this arrangement much better

than the other, though there are many of the articles which I do not recollect to have remarked in our little cabinet.

MRS. R.

That is because they are of little importance in learning the first principles of the science, and would only confuse you at first. The celebrated traveller, Humboldt, has invented a set of algebraic signs for representing rocks; but, as that would only puzzle you, I have endeavoured to render it in terms more intelligible to you.

HUMBOLDT'S GEOLOGICAL TABLE.

Tertiary or Diluvian.

Paris Limestone.
Sandstone, including remains of wood.

Secondary or Sedimentary.

Chalk.
Green Sandstone, with remains of wood.
Jura Limestone.
Sandstone of Königstein.
Shell Limestone.
Variegated Sandstone.
Rock Salt and Alpine Limestone.
Coal, Red Sandstone, and Porphyry.

Intermediary or Fragmentary.

Serpentine and Diallage.
Porphyry and Syenite.
Granite and Syenite.
Porphyry and Syenite.
Limestone with organic remains.
Mica Slate.
Porphyry and Clay Slate.
Clay Slate.
Organic Limestone and Clay Slate.
Organic Limestone.
Gray Wacké, or Conglomerate Slate.

Primitive.

Serpentine and Diallage.
Clay Slate.
Gneiss.
Granite.
Clay Slate.
Mica Slate.
Granite.
Primitive Limestone and Mica Slate.
Mica Slate and Gneiss.
Porphyry and Gneiss.
Gneiss and Granite.
Granite, the Foundation Rock.

CONVERSATION ELEVENTH.

CONSOLIDATION AND HARDENING OF ROCKS.

MRS. R.

Now you must have all your chemical knowledge in readiness, for we must leave, for a time, the great speculations which we have been discussing, and examine the materials of rocks a little more minutely, to try whether, with the assistance of the theorists, we can discover in what manner they have been consolidated; that is, supposing them to have been in a soft state at the bottom of the sea, how have they been hardened?

EDWARD.

This, I presume, will bring the Huttonians and the Wernerians into closer contact than we have hitherto had them.

CHRISTINA.

And we shall have experiments, I dare say.

MRS. R.

I am sorry, my dear, to disappoint your expectations; for, though Sir James Hall, Mr. Watt, and a few others, have tried experiments in support of the Huttonian doctrines, they are of such a kind that we cannot easily repeat them.

EDWARD.

Previous to hearing their several arguments, I should be disposed to think that, at first sight, Dr. Hutton will find it easier to account for rocks hardening after being melted, than Werner will to explain their consolidation after being deposited from a solution.

MRS. R.

You will, however, find many of the arguments so strong on both sides, that perhaps you will not find it easy to say which is the most conclusive; but, as you imagine that the Wernerians will have the worst of the argument, I shall begin with their account of consolidation, which goes to prove that the rocks have assumed a hard and solid

form by crystallization, by drying after the waters had subsided, or by the infiltration of a cement dissolved in a fluid menstruum and deposited in the interstices.

EDWARD.

I rather think that these would produce but a very imperfect consolidation.

MRS. R.

So think the Huttonians, who say that the rival theory might in this respect pass for "the invention of a barbarous age, when as yet sound philosophy had not alighted on the earth;" but, though upon theory they allege that aqueous solution can never, by any kind of precipitation, wholly fill up the interstices of a porous body, yet by facts it may be shown that it actually does so under our eyes, as in the instances which I have already mentioned at Matlock, Tivoli, and the Geiser springs in Iceland.

EDWARD.

But these new-formed rocks may not be so hard and well consolidated as granite and marble.

MRS. R.

Both English and Italian architects think otherwise; for the newly-formed stone at Matlock is, on account of its beauty and durability, employed in building over all the adjacent country, and almost all the buildings in Rome are constructed of the Tivoli stone, whose formation is still going on; even the magnificent front of St. Peter's Church is faced with it, and it forms the exterior covering of the Coliseum. No calcareous stone, however, is so hard as granite or quartz rock.

EDWARD.

Ay; but the flinty depositions which you mentioned as taking place at the Geiser springs must, I suppose, be as hard.

MRS. R.

I have another instance still more conclusive. The waters of Loch Neagh, in Ireland, in consequence of holding flint in solution, convert pieces of wood into stone, by depositing the flint in the pores and interstices of the wood.

CHRISTINA.

That must be a very extraordinary thing to see.

MRS. R.

The process is too slow, my dear, for you to see it in actual operation; you cannot see it any more than you can perceive the motion of the hour-hand of a watch or the shadow on a dial; but, when you see the specimen, one part flint and another wood, you must be convinced of the fact.

EDWARD.

I should like very much to see a specimen of this.

MRS. R.

I am sorry I have not one, but I examined a fine one a few years ago, which was said to have been taken from a tree *still growing* on the margin of the lake. Whether this was so or not I cannot affirm, but in several parts of the specimen the wood was quite fresh, while the stony part was as hard as a flint pebble. Now, it is certain, I think, that this must have been produced by water, and not by flint melted by heat, for the

water of the lake is reported to be more than usually cold, and the tree could not, in all probability, reach so deep as the Huttonian region of heat, if any such region exists.

EDWARD.

But this may be a solitary and singular instance.

MRS. R.

On the contrary, numerous specimens of a similar kind are brought from the same place, as well as from many other parts of the world. It will not, therefore, avail the Huttonians to oppose to fact their speculative arguments concerning the impossibility of a solution shutting up the pores of a body, to the entire exclusion of the menstruum.

EDWARD.

I think I could explain, from chemical principles, how the process goes on; for, supposing a crevice in the wood or an interstice between its fibres, the water containing the dissolved flint enters, and, having deposited this, it must become specifically lighter, and will necessarily ascend, while a fresh portion of the solution, which is specifically heavier, will descend to supply its place;

and, as the exclusion of free water is an indispensable law of crystallization, this process will go on till the whole interstice is filled with flint.

MRS. R.

I must thank you for this very clear and distinct explanation, which I can assist you in proving to be correct, by the actual existence of water, holding flint in solution, being found in the crevices and cavities of rocks.

EDWARD.

That is a fact which I could not have anticipated.

MRS. R.

Geologists call such cavities, and indeed all cavities in rocks, *druses;* and Parkinson tells us, that a solution of flint in water, in the proportion of fourteen grains to twenty ounces, has been found in the druses at basaltic columns. Dr. Plott describes iron stones as big as the crown of a hat, hollow and like a honeycomb, and containing *a pint of sweet liquor*, which is eagerly sought for and greedily drunk by the workmen. It is even found sometimes in the quantity of a hogshead, in the very bosom of the rock. Dr. Woodward also

mentions stones from the size of a walnut to two feet in circumference, containing in their centre a fluid as thick as cream; but Werner mentions a still more remarkable circumstance, in the existence of druses containing so much water as to endanger the lives of the miners.

EDWARD.

Had those rocks been melted by heat, this water could not have been there, I think, for it would have been converted into steam and exploded with irresistible force. A single drop of water would in this way blow up the contents of the largest metal furnace that ever was constructed; and, I think, a hogshead, or even a pint of water, contained in the centre of a melted rock, would explode in the same way.

CHRISTINA.

I think, mamma, I can comprehend all that you have told us about the wood converted into stone, except that, in most pieces of wood, there are no interstices or crevices for the water to get into.

MRS. R.

I can explain that also. When a piece of wood is left for a long time soaking in water, and more

particularly when buried in moist sand, mud, or boggy ground, so as to exclude the air, it soon undergoes a change of structure, such as you may see in the wood found in peat-bogs. In this state, if there be enough of water, the fibres will partially separate, and become looser and more distant, but without destroying the texture of the wood. When it is in this state penetrated by flint water, the process formerly described goes on, and the flinty deposition not only takes the very form of the fibres and structure of the wood, but often the colour also, when it is itself colourless. From the look of the specimens, you would not hesitate to say they are blocks of wood, and only find out their conversion into stone by their great weight and flinty hardness.

EDWARD.

I cannot conceive how Dr. Hutton explains those remarkable facts.

MRS. R.

He says that the flint was injected into the wood in a melted state; and, as a proof of this, he alleges that the woody and flinty portions are always found distinct, and never graduating into

one another, as would be the case had they been formed by the infiltration of water. In the specimens, however, which I have examined, this line of separation is not distinct; but, even if it were, it would only prove that the flinty water had not yet penetrated that part of the wood which remains fresh, by its having been above the level of the water, or from the closeness of its texture.

EDWARD.

It strikes me, also, that the injection of melted flint into the wood, is inconsistent with what you just told us of the colour and texture of the wood being preserved in the petrified specimens; for surely the violent injection would displace the fibres, and I cannot conceive how it could assume, on cooling, their colour and texture.

MRS. R.

True; and in some of the specimens also I may tell you that the woody texture is so finely and minutely preserved, that they will bear the closest inspection of the microscope.

EDWARD.

I presume that the Huttonians believe, also,

that the flint pebbles in chalk have been injected in the same way.

MRS. R.

These pebbles are a subject of much geological interest as well as difficulty, and you are right in your conjecture as to the explanation of the Huttonians, who say the melted flint has been forced up through the chalk rocks, in the same way as water may be forced to penetrate through gold, or quicksilver through wood, in which case globules will be formed on the surface.

EDWARD.

I cannot agree to this opinion of injection, unless I am told in what state of hardness or softness the chalk was at the time. If it possessed any degree of hardness, then every individual nodule of flint must have occasioned a rent, which I do not recollect having observed. If, on the other hand, the chalk were soft, the melted matter would infallibly have enclosed pieces of chalk, at least in some of the nodules; and this, also, I have never seen in chalk flints. I think, also, that it is very singular that mere nodules should have been thrown up, and not large masses of flint.

MRS. R.

It is also a strong objection, that the nodules are frequently found to exhibit very delicate vegetable impressions, which must have been destroyed by a melting heat.

EDWARD.

If Werner suppose them to have been infiltrated into the chalk by the percolation of water, in the same way as he accounts for the petrified wood, I think some strong objections will lie against the opinion.

MRS. R.

This is his explanation; and the Huttonians object, that there is no trace of the water remaining, nor of the course it took.

EDWARD.

The same objection, however, will apply, I think, with equal force, to their own theory of a melted injection; but I should say that the flints, such as I have seen them in the chalk quarries in Kent, are too uniformly placed in beds to have been produced either by random injection or infiltration.

MRS. R.

It has often occurred to me, that the difficulty would be best solved by supposing them to be rolled water-worn pieces in the chalk deposite.

EDWARD.

I think that this explanation is much more simple and natural than the others.

MRS. R.

Sandstone is another of the substances, the manner of whose consolidation is keenly contested; the Huttonians asserting, that the particles which compose it were united by incipient fusion, and the Wernerians, that they have been joined by a watery cement, the basis of which is usually iron or lime.

EDWARD.

I confess I think the cement the more probable of the two.

MRS. R.

And it is the more so, that the supposed incipient fusion is a state of softness almost unknown in chemistry; for complete melting comes on almost instantaneously, as you may have remarked when melting lead.

EDWARD.

But are there no recent instances of sandstone being produced, like the limestones of Matlock and Tivoli?

MRS. R.

Some instances are recorded, and, though not so well marked as those of the limestone, are sufficient, I think, to disprove the theory of incipient fusion. For example: we are told by Saussure, that in the neighbourhood of Messina, where grits are quarried near the sea-shore, the cavities formed by their extraction are soon filled with sea-sand, which, in a few years, is solidified, having its particles agglutinated by the calcareous matter introduced by the sea-water. Bowles remarks that, in the neighbourhood of Cadiz, the sea possesses the same power in cementing together the fragments of brick, mortar, and rubbish thrown on the shore, and, with the shells, forming a solid mass of stone; and Flurl gives a similar account of fragments of rocks cemented into a stony mass, at Hugelfing, in Bavaria.

EDWARD.

Those instances, I think, are quite conclusive.

MRS. R.

There are many others of a similar kind: for instance, we are told by King, in the Philosophical Transactions, of a vessel which was stranded off the coast of East Lothian, whose wreck remained under water thirty-three years, when it was partly brought into view by a storm, and pieces of iron, ropes, and wood, which were thrown out on the shore, were found to be covered with a stony substance, so hard and adherent, that it was with difficulty that it could be detached. On examination, it proved to be the sand of the bottom of the sea, cemented, by the agglutination of its particles, into stone, quite similar to sandstone. We have the same authority for similar concretions being found on the iron pivot of a brass swivel-gun, which was dragged up in the Downs, and which, from its construction, it appeared, must have been there two hundred years, at least. A very curious fact, tending to confirm these accounts, was discovered by Dr. Fothergill, when walking on the pavement in London, before the taking-down of the iron sign-rods: he found that his staff produced a different sound from the stones immediately under them, than

on any other part of the pavement. He had the curiosity to have some of these stones taken up, and, on examination, found that the dropping of the water, impregnated with iron from the sign-rods, had rendered the stone on which it fell so hard, as not to yield to the usual instruments. The same thing is also well illustrated by the puzzolanum, and by ironstone reduced to powder and mixed with water, both of which substances became as hard as stone when used as cement for harbours.

EDWARD.

This, I think, is an experiment directly in point.

MRS. R.

Zimmermann made one still more conclusive, so far as sandstone is concerned, by mixing one part of filings of iron and three parts of sand, sprinkling it with water, and letting it stand six months to consolidate. At the end of that time, he found the vessel burst by the expansion of the oxygenated iron, and the sand so firmly compacted, that the mass thus formed could not be broken but by a chisel and hammer.

EDWARD.

From these facts, I should have no hesitation in concluding, that sandstone, as well as limestone and flint nodules, have been produced by water rather than by fire.

MRS. R.

With regard to limestone, Sir James Hall proved that it was at least possible that it may have been melted; for, though it will not melt in ordinary circumstances, even by intense heat, yet, when it is subjected to compression, by a weight much less, too, than the weight of the waters of the sea, it may readily be fused.

EDWARD.

But, though this may be so, it will not follow that limestone-rocks have actually been melted; for surely they will not assert that the rocks at Tivoli, Matlock, or the coral reefs at the tropics, have been melted. In the instance of the coral limestone, also, the coral would be obliterated, which it is not in the specimen in our cabinet.

MRS. R.

Sir James, aware of this objection, made an experiment on purpose to obviate it, and succeeded in melting limestone, containing coral and the most delicate shells, without injuring them in the least.

EDWARD.

Then I should say that this experiment, so far from supporting the Huttonian theory, is in direct opposition to it, by proving too much; for, if the most delicate shells are not injured in appearance or texture by a melting heat, how does it happen that we do not find as many shells in Carrara marble and granite as in coral rock and shale, all of which, according to the theory, were consolidated at the bottom of the sea?

MRS. R.

This, indeed, is a circumstance which I must give you credit for detecting, but to which I know not what answer a Huttonian would make.

EDWARD.

It occurs to me, that coal is another substance which could not possibly be consolidated by heat,

particularly if it be produced, as Dr. Hutton supposes, by the deposition of concentrated smoke at the bottom of the sea.

MRS. R.

This is only one of the sources from which Dr. Hutton derives coal; but the greatest portion, he thinks, is supplied by rivers which run from mosses, and are of a dark colour, as all rivers are that flow through an uncultivated country.* So jar, also, from thinking, as you do, that coal could not be consolidated by heat, Dr. Hutton thinks it one of the substances most favourable to his theory, and boldly says, "It is inconceivable to have this effect produced from water; we might as well say that heat were to be the cause of ice."

EDWARD.

Even were it granted that the materials of coal supposed to be carried into the sea from smoke, mosses, and forests, were deposited on its bed

* Lochead says, that foiest rivers, though dark, are not so much so as moss-rivers, and deposit little sediment.—*Nicholson's Journal.*

(though, from their being lighter than water, I cannot conceive how they would ever sink), it is by no means obvious in what manner heat would form them into coal.

MRS. R.

This, it is supposed, was effected by compression, as in the case of the limestone and basalt experimented upon by Sir James Hall; and that this actually took place, they try to prove from the fact that coal is often deprived of its bitumen, and in the form of charcoal or cinders, exactly like those of an ordinary fire, while soot is found in the vicinity,* and sometimes bitumen and pitch, as if expelled from the coal-bed by heat, either in separate masses or diffused through rocks in contact with the coal. Besides, coal-beds are found alternately with basalt and other rocks, that are, as Mr. Playfair says, "the decided progeny of fire."

EDWARD.

I should have anticipated more direct proofs

* Dr. Knight's New Theory of the Earth, p. 199, 8vo. Edinburgh, 1818.

than these from the confident manner of talking which you quoted from Dr. Hutton.

MRS. R.

You will find it a good rule, in general, to suspect an argument to be weak when the arguer seems to be over confident, on the same principle as you would suspect the truth of what a person would confirm with an oath that was uncalled for. Dr. Hutton, accordingly, has been unfortunate in his account of coal; for he says it has been melted under a diminished pressure, whereas limestone, particularly when crystallized, requires a very great pressure. But, unfortunately for the system, sparry or crystallized limestone is found very generally diffused through coal in their white seams, and, of course, the two substances could not, as the theory states, be fused together, the one with a small, and the other with a great pressure. What I have said of the limestone will apply also to pyrites, the yellow metallic substance so often found diffused through coal, and consisting of a nitric sulphurate of iron. This, also, according to the Huttonians themselves, requires a great pressure, and, of course, could not be produced by fusion along with coal, as we find it actually is.

EDWARD.

As the Huttonians evidently fail in proving coal to be produced by fusion, I hope the Wernerians may succeed better, for I should be sorry if so interesting a subject were left unexplained.

MRS. R.

To understand their account, it will be requisite for you to recollect the process of the formation of bogs and marshes, as it is from these that Werner derives coal. What I told you, also, of the change produced on wood by being long exposed to moisture and kept from contact with the air, will be of use here, as wood, in all stages of change, is often found in coal-fields, in the same way as in peat-bogs.

EDWARD.

That is a very strong circumstance in favour of the alleged origin.

MRS. R.

There are some facts, indeed, connected with this, which prove this origin beyond question, as you will admit, when I tell you that specimens of wood are often found partly converted into coal

and partly unchanged, or petrified by some other mineral.

EDWARD.

This will, at least, be direct proof that wood may be converted into coal.

MRS. R.

One instance of this kind is mentioned by Brand, in his History of Newcastle, as having been brought from Iceland, by Sir Joseph Banks; Dr. Rennie, in his Essay on Peat-moss, gives a still stronger example. In the parish of Kilsyth, he tells us, there was found, in a solid bed of sandstone, the trunk of a tree in an erect position, the indentations of the bark and marks of the branches being in many parts of it still obvious. It rose from a bed of coal below the sandstone, and the roots which reached the coal, as well as the bark for an inch thick round the trunk, were completely converted into coal, while the centre consisted of sandstone. This specimen I have myself seen in the parsonage garden of Kilsyth, and this description is most accurate. Sir George Mackenzie lately found a specimen precisely similar, in the face of a sandstone rock in Lothian, and I have seen numerous specimens of bamboos

and reeds in the sandstone quarries of Glasgow, with the bark converted into coal and the centre filled with sandstone.

EDWARD.

But would not this prove that sandstone, also, was derived from wood?

MRS. R.

No: it would only prove that the centre had been destroyed and removed; for the sandstone is not chemically composed of vegetable substances, but the coal is.

EDWARD.

Still, I cannot conceive by what process the conversion is effected.

MRS. R.

By a natural process, evidently: being a continuation of that which converts mosses and marshes into peat. Nay, it is supposed not to stop at the formation of coal, but, by a continuation of the causes, the coal becomes jet, and even amber. The eminent chemist, Fourcroy, in proof of this, mentions a specimen in which one end was wood, little changed, and the other

pure jet; and Chaptal tells us, that at Montpellier there are dug up whole cart-loads of trees converted into jet, though the original forms are so perfectly preserved that he could often detect the species; and, among others, he mentions birch and walnut. What is even more remarkable, he found a wooden pail and a wooden shovel converted into pure jet.

EDWARD.

Then, I suppose, from all these details, that coal might be formed artificially, by imitating the natural process.

MRS. R.

Mr. Hatchett made many ingenious and successful experiments with this design, and Dr. Macculloch has more recently succeeded in actually making coal. One of the strongest instances of the process, is the existence of a great quantity of wood only half converted into coal, at Bovey, near Exeter; this has been much discussed by the Geologists; but there is a bed of coal found at Locle, on the Continent, which is said to have been formed almost within the memory of man, though I have not yet seen any good account of it.

CHRISTINA.

I confess, mamma, that I do not feel so much interest as I expected in these accounts of coal.

MRS. R.

Probably not; but you cannot expect all the parts of a science to be equally interesting; and I can scarcely promise that you will be more entertained with the subject of rock-salt, though I think it will be useful to tell you something of its supposed history.

EDWARD.

I differ altogether with Christina, as to the interest of the subject of coal: I liked it very much, and I dare say rock-salt will be a subject no less curious and instructive.

MRS. R.

It is, if not the most interesting, the most puzzling substance to account for in Geology. Hutton, of course, says it has been formed by the heat of the central fire evaporating the water of the sea, and melting the residuum into a crystallized mass.

EDWARD.

Then it would not be difficult to imitate such a process, and produce rock-salt artificially.

MRS. R.

It would not only be difficult, but impossible; for the rock-salt contains no magnesia or lime, as sea-water does, and these would not be driven off by heat; and, farther, no method yet known of applying heat will form it into crystals like those of rock-salt. There is another circumstance strongly against the operation of the Huttonian heat upon rock-salt,—it being always found in a position nearly horizontal, and among rocks of the newest formation, particularly gypsum or Paris plaster; but, had this violent heat taken place, it must have been either exploded, or at least considerably elevated, along with the alternating rocks.

EDWARD.

I think I could give a more satisfactory explanation of its origin; for suppose, in the natural wearing-down of the rocks, a mountain of salt, like those described to exist in the Sahara, comes to be exposed, all the water running off from it

would be loaded with salt, and would overload, in the same way, part of the sea into which it flows; the consequence would be, a precipitation of the superabundant salt, and this would go on so long as the supposed mountain continues to furnish salt. After this, it will be covered with other beds, which will protect it from being dissolved again, as it would be were it exposed to the common sea-water.

MRS. R.

This is ingenious enough, though I fear it is not unobjectionable; but I find I must leave you for the present. At our next lesson, we shall consider the subject of mineral veins and the metals found in them.

CONVERSATION TWELFTH.

MINERAL VEINS.

EDWARD.

I AM not sure that I understand what is meant by a mineral vein.

MRS. R.

Then I shall explain it by a very familiar illustration. You have often remarked, in dry summer weather, cracks and chinks in the footpaths through the fields, caused by the shrinking of the clay deprived of the moisture that previously swelled it. Some of these cracks, you may have remarked, are small, others wide and deep, and running out to the length of several yards. Now, suppose that you filled one of those footpath-cracks with melted lead or silver, or gold, or with basalt or granite, or turned a stream of water

into it, holding a solution of lime, like that of Matlock or Tivoli, till it were filled with limestone, it would in all those cases be a *mineral vein*, or what, by the miners, is called a cross-course, a fault, a trouble, a dyke, and fifty other similar names, according to fancy.

EDWARD.

This I can fully comprehend, and can anticipate that it will be a very interesting subject.

MRS. R.

In a geological point of view, it is so. For exaxample: it often serves to determine the relative age of rocks, as the vein must, in most cases, be formed after the rock which it traverses.

EDWARD.

I should suppose not merely in most, but in all cases; for the rock could not be rent till it was formed; and I understand you to say, that all veins are similar to the crack in the footpath afterwards filled up.

MRS. R.

Geologists, however, have discovered that this is not uniformly the case; for there are very nu-

merous small veins, from the breadth of a thread to that of a few inches, which seem to have been formed at the same time with the rocks they run through, and have, in consequence, been called *contemporaneous veins;* they are usually composed of similar materials to their containing rock, and they never cross more than one bed. But their contemporaneous veins have little to do with the keen controversy which has been maintained, whether veins have been filled from above by water, or from below by fire.

EDWARD.

The Huttonians, I dare say, will say the cracks have been made by expansion; and the Wernerians, that they have been caused by subsidence.

MRS. R.

Precisely so: and the Huttonians also allege, in support of this, that the deeper you trace a vein, the wider it becomes, while the Wernerians deny the fact, and maintain that veins terminate below, being in the form of a wedge, the edge of which is lowest.

EDWARD.

And is the truth not ascertained?

MRS. R.

I am not aware that it has ever been satisfactorily settled; but Werner and his disciples, for one thing, were much better acquainted with practical mining than Dr. Hutton, Mr. Playfair, and Sir James Hall; and that gives the Wernerians the decided advantage of authority.

EDWARD.

Perhaps we might be nearer the truth if we proposed an accommodation between the two theories, and said that some veins have been filled from below and some from above.

MRS. R.

This would certainly obviate many difficulties and inconsistencies in the two theories: for instance, the numerous veins which exist in rocks nearly horizontal could not be explained consistently with the Huttonian theory of fissures being formed by the rending of the rocks from the expansion of heat below; as, in that case, the rocks, instead of being horizontal, would be raised to a considerable angle. I remarked a striking example of this on the north end of the

Great Cumbræ Island, in the Firth of Clyde, where five or six large veins of basalt, or *whin-dykes,* as they are called, run nearly parallel, at the distance of a few feet from each other, through a bed of old red sandstone, nearly horizontal. In the Island of Arran, where the sandstone is also nearly horizontal, it is traversed in all directions by similar whin-dykes, crossing one another in such a manner as would make it difficult to explain how the divided parts of the rock were supported during the consolidation of the veins, did not these crossings undeniably indicate that the veins had been formed at different periods.

EDWARD.

On the supposition of an expansion from below, I should imagine that veins would be most numerous in the vertical or primary rocks.

MRS. R.

This, however, is not the case; for, though metallic veins are more numerous in these, yet basaltic and limestone veins are no less so in the newer and horizontal rocks. But the Huttonians further argue, that the fusion of the substance of a vein is indicated by the walls inclosing it being more

hard and compact than the adjacent rock, by their being sometimes impregnated to a certain extent with the matter of the vein, and sometimes even exhibiting a burnt appearance, particularly where whin-dykes or veins of basalt cross a bed of coal. The same is true of fragments of the adjacent walls, which are frequently found in the midst of a vein, and are expressly termed *riders.* All these phenomena, they argue, plainly prove the injection of melted matter, and are consistent with deposition from water.

EDWARD.

Although I think that compromise between the two theories is nearest the truth, yet would I not willingly let any of them have the argument all their own way; and, as to this changed appearance in the walls and riders of veins, held out as indicating a contact with melted matter, I think it more naturally indicates the contrary; for melted metal will not pass through the substance of a rock and impregnate it, any more than a piece of sandstone would by dipping it in melted lead. Melted metals will not even penetrate a hair's breadth into loose sand, of which it is well known moulds are made for casting. But none of these objections will apply to a watery solution, which

would readily soak into almost the hardest walls of a vein.

MRS. R.

All this I think ingenious and natural, and you may also take into account that these appearances of induration are by no means constant. The charring of the coal in the neighbourhood of basaltic veins or troubles, we must, I suppose, give up to the Huttonians, though Dr. Thomson endeavours, with some plausibility, to explain it away, and to refer the effect to water.

EDWARD.

But, independently of the termination of veins, I should be led to think, that, if they were all filled from below with melted matter, they would give evidence of it from the uniform compactness of their substance.

MRS. R.

This, however, is not the case; for, though many of them are filled with substances that exhibit the appearance of having been melted, others are found to contain not only sandstone, but clay, gravel, sand, and bowlders, materials which obviously could never have been injected in a fused state from below. Williams, in his Mineral King-

dom, mentions such veins, and De Luc, in his Letters to the Queen, has given an example of a vein filled with shells.

EDWARD.

In those instances, at least, Dr. Hutton's theory will not afford an explanation of veins.

MRS. R.

There is another most important appearance of veins, for which it also fails to account satisfactorily; for, on the supposition of an injection of melted matter from below, we would naturally expect to find the substance of a vein a mass of matter confusedly crystallized, without any other arrangement than exact conformity to the inequalities of the walls, which would exist in the smoothest fissure.

EDWARD.

This was precisely the notion I had formed of metallic veins from your description.

MRS. R.

In many veins, however, this is not the case; for we often find a pair of thin plates or leaves of

one mineral substance lining the walls of a vein, and these succeeded on their inner side by another pair of plates of a substance quite dissimilar, and so on, there being often a great number of successive plates disposed in this manner before we reach the middle of the vein. Each succeeding layer, indeed, seems to have been deposited on the preceding, and in such a way that the crystals of the second layer are always impressed by those of the first. In a vein of this sort at Gersdorf, in Saxony, which is about nine feet wide, there are sometimes no fewer than forty distinct parallel plates, consisting of calc-spar, fluor-spar, lead-glance, gray copper-ore, with heavy spar and a small proportion of quartz. There are similar examples at lead hills in Scotland and in the Island of Arran.

EDWARD.

I think it is obvious enough that this structure could not have been produced by the injection of melted matter; for, if this had been the case, I know no law of chemistry that would have caused the substances to arrange themselves in this regular manner. Besides, I think that, had so many substances, so different in weight as lead and fluor-spar, been thrown up in a melted state, as

they could not be supposed to cool all at once, the heaviest, instead of arranging itself along the walls of the vein, would fall to the bottom and exhibit regular beds from below upwards, instead of vertical plates.

MRS. R.

This is one of the objections which the Huttonians urge against the Wernerian account of veins: that they are not of this structure, arranged according to the specific gravities of the substances, as they ought, say they, to be, if the veins had been filled by depositions from water.

EDWARD.

In mechanical depositions this objection would hold good, but not in those that are crystallized; for, when crystals are formed from a solution, they do not all subside, but attach themselves as readily to the sides as to the bottom of a vessel; and this will accord exactly with what you have told us both of the laminated structure and the impressment of crystal.

MRS. R.

There is one strong objection to the narrowing

of veins as they descend, and their being filled with melted matter, which I think it will be worth while to consider. It is founded on the improbability of a sufficient quantity of melted matter being thrown up through a narrow opening, to fill a large vein; for suppose the melted matter to have been thrown up in the manner of a *jet-d'eau*, it is plain that the vein could never have been filled in this manner, because the matter which would fall back from the first jet would retard and reduce the quantity of that which succeeded, and so on, till the process would soon be stopped; and this would take place long before the fissure, even supposing it small, could be filled. In the meantime, the melted matter, being now removed from the region of heat, would cool and harden, and prevent all renewal of the process, without the production of a new fissure.

EDWARD.

Yes; all this would happen were it to be thrown up in jets, though I do not know whether the theory states this; but, if the melted matter were to rise slowly through the fissure, like the rising froth in a tankard of porter, the objection, I conceive, would not apply.

MRS. R.

This, at least, is very plausible. There is only one other appearance respecting veins, which I shall point out to you, naturally arising from the manner in which the original rent has been made. For instance: a coal-bed has been split across, and the rent filled up with basalt; the miner works till he arrives at this basalt vein, or *trouble,* where the coal is cut off, and he of course must dig through the basalt before he can get any more coal. Now, the remarkable circumstance is, that he has little chance of finding the coal on the other side of the basalt at the same level as that which he was previously working, but either above or below it, according to circumstances.

EDWARD.

Oh! I can comprehend this; for, unless the coal-field was perfectly horizontal at the time of the rent, the lower side would sink farther than the upper, and throw it out of the level.

MRS. R.

Precisely; and the same circumstance occurs when one vein crosses another, as at the Tin

Croft Mine, in Cornwall, where the lead and copper veins are heaved towards the south by a non-metallic cross-vein.

EDWARD.

This circumstance, I suppose, will accord with both the theories.

MRS. R.

So far as I know, it will; and now, having given you an outline of the chief doctrines and arguments of each, I shall leave you to study them for yourselves, in the works which have been written by their several supporters, the best of which I shall select for you. Dr. Hutton's own work is too confused, ill-digested, and ill-written, to interest you; but Mr. Playfair has written eloquently and beautifully in his support. Werner has published little himself, except a Theory of Veins; but Kirwan, Jamieson, and Murray, have advocated his principles with great spirit. Most of the more modern writers, such as Philips, Kidd, Greenough, and Brande, steer a middle course; but the most instructive, though not always the most interesting authors, are those who describe what they have examined in nature, sometimes,

though not always, unbiassed by theory: such as Saussure, Humboldt, Webster, Macculloch, Conybeare, Brogniart, Von Buch, and many others; all of whose observations will not as yet be intelligible to you, but, as you advance in a knowledge of the science, will require to be carefully studied.

EDWARD.

I have always been expecting to hear more about the shells found in rocks, than either of the theories seem to give.

CHRISTINA.

And I have as anxiously looked forward to a grand account of the deluge.

MRS. R.

You shall both be gratified upon these points as we proceed with the next theory of Geology, if it may be called so, which is both the oldest and the newest.

EDWARD.

This I cannot understand.

MRS. R.

Mr. Granville Penn affirms that the account which he has lately published of the origin of rocks, mountains, valleys, rivers, and lakes, is the same as that of Moses; but, as it was never explained before as he has done it, I may well call it both the oldest and the newest, and I shall, at our next lesson, give you a few of the arguments upon which it is founded.

CONVERSATION THIRTEENTH.

MOSAIC GEOLOGY, AS EXPLAINED BY MR. PENN.

MRS. R.

The excellent Geologist to whom I am now to introduce you, is a remarkable exception to the usual character of this class of philosophers; for he seems to have little relish for the romantic wanderings and fanciful theories which, time out mind, have brightened their day-dreams, and cheered them on to perilous adventures, among precipices, glaciers, and volcanos.

CHRISTINA.

Then, I am afraid, I shall not like him so well as the others, if he is a mere dry describer of facts.

MRS. R.

I did not say so: on the contrary, he is a very spirited and interesting writer, and I have no doubt he will become a great favourite with Edward, as he not only argues his points very cleverly and forcibly, but, before he commences his own structure, he sets himself to demolish all the previous systems of Geology, root and branch.

EDWARD.

But, if he succeed in this, all that you have previously taught us will be rendered of no use.

MRS. R.

You need not fear that, for most of our best knowledge is acquired by unlearning error; and it is always useful to know the several opposite views held by distinguished men on the same subject, no less than to be acquainted with the history and progress of the sciences which we study.

EDWARD.

I confess, however, that I should not like to give up some of the geological opinions which I have already imbibed.

MRS. R.

That is exactly the feeling which so often prevents the abolition of error and the establishment of truth.—But let us see how Mr. Penn proceeds as the "architect of ruin," as Burke might perhaps have called him.

CHRISTINA.

If he is fond of ruins, I have no doubt I shall like him.

MRS. R.

He is at least an enthusiast for his system, and that seldom fails to rivet attention. He makes no distinction between Wernerians and Huttonians, but calls all previous theorists *Mineral Geologists,* in contradistinction to himself, the MOSAIC GEOLOGIST.

EDWARD.

But he surely does not mean to say that there is no difference between the system of Werner and Hutton.

MRS. R.

No; but he says they agree in the grand object of their inquiry, being to discover the mode of

the *first formation* and *subsequent changes* of the rocks and other materials on the earth's surface, as deduced from observation of their present appearances. The common conclusion of the mineral Geologists is, that the phenomena of rocks indicate their former existence in a chaotic ocean, from which they were separated during an unassignable series of ages, and consolidated as we now find them. This general position Mr. Penn thinks is gratuitous and wrong, being in opposition both to the great principles of Newton and to the historical facts of the Mosaic record.

EDWARD.

If he prove this, it will indeed ruin, at least the Wernerian theory: Dr. Hutton, if I recollect rightly, does not presume to arrive at a first formation.

MRS. R.

Newton's principles, however, are equally hostile to the Huttonian doctrine of successive worlds, for he not only says that "the growth of new systems out of old ones, without the mediation of a Divine Power, seems to me apparently absurd;" but also, that "all material things seem to have been composed and variously associated in the

first creation by the counsels of an Intelligent Agent; for it became Him who created them to set them in order; and, if he did so, it is unphilosophical to seek for any other origin of this world, or to pretend that it might rise out of a chaos by the mere laws of nature; though, being once formed, it may continue by those laws for many ages."

EDWARD.

But might not God create the world in a state of chaos, and, after imposing upon it the laws of chemical affinity, leave these to operate in the same way they now do?

MRS. R.

The conjecture is plausible enough, but such fancies are not good philosophy. Newton himself sometimes indulged perhaps too much in similar suppositions, as when he talked of some kind of ether as the cause of gravity, and when he said, "*if* the earth were formed of a uniformly yielding substance, and *if* it were to become deprived of its motion, it would settle into a perfect sphere." The Mineral Geologists, without thinking of Newton's "*if*," state this as the fact.

EDWARD.

Their error appears to be in not carrying their analysis beyond *particulars*, while Newton proceeds step by step, till he arrives at the grand cause, an INTELLIGENT CREATOR.

MRS. R.

This is indeed the origin of their error; and Mr. Penn, therefore, ranks them among the philosophers who, as Lord Bacon says, impede knowledge, "by slipping off particular sciences from the root and stock of universal knowledge." De Luc, whom I have so often mentioned, was aware that the Mineral Geology did not agree with the grand Newtonian principle of referring to the Creator, and he makes the singular apology that the term creation is physically unintelligible. To me, however, it is quite as intelligible as the term chaos.

EDWARD.

If I rightly understand your sketch of Mr. Penn's views, he thinks that the whole globe was *created* in the same way as plants and animals.

MRS. R.

Precisely so: for if, with Newton, we refer similar appearances to similar causes, we must conclude that the three great classes of animals, vegetables, and minerals, have a community of system, the earth being fitted to support the two first, and they again being necessarily dependent on the earth. They are, therefore, constituent parts of one whole, and the *first* formations of each must accordingly be referred to the same *cause* and to the same *mode*.

EDWARD.

That is, I suppose, if we can prove one of these to have been created immediately by God, it will follow that the others, also, have been formed in the same way.

MRS. R.

Such is Mr. Penn's argument, and it appears to be incontrovertible. He goes on to support it by proving the individual creation of animals and plants.

EDWARD.

He might have taken it for granted, I think; as it is not, so far as I know, denied by any body.

MRS. R.

You will, however, see his application more strikingly, from his ingenious mode of proof. If we trace back, then, the generations of men, we shall ultimately arrive at a first man, or parent of all; and, though it will not alter the force of the argument whether this first man was created in a state of infancy, boyhood, or manhood, it is most probable that he was formed mature, with a bodily structure similar to our own, having his soft flesh supported and strengthened by means of bones. The first inquiry, therefore, will be, what is the use and the formation of bone?

EDWARD.

I confess, I cannot perceive how this is to bear upon Geology.

MRS. R.

You shall soon see that; but you must allow me to develop the argument. The use of the bones, we are told by anatomists, is to give shape and firmness to the body, to serve as levers for the muscles, and, in the case of the ribs, to protect the heart and the lungs, while the bones of the skull protect the brain. But, when first formed,

bones are very soft and pulpy, as is seen by examining the chick in an egg during the progress of hatching; and it is only by degrees that the bones become perfectly hard.

EDWARD.

I have often remarked this at table, in lamb and veal, in which the bones were soft and gristly.

MRS. R.

This gradual hardening is the process of the formation of bone *at present*, but we must not thence conclude that the bones of the first man were at first soft, and then gradually became hard; for he was at once created perfect. Yet, were a bone of the first man now remaining and given to an anatomist, he could not probably tell, from its appearance, that it had not been formed like other bones; just as the Mineral Geologist infers from the rocks which now exist, that they have been precipitated and crystallized from the waters of chaos, or ejected from the bowels of the earth, melted by fire.

EDWARD.

Ah! I now perceive the ingenuity of the argument: the conclusion of the anatomist, that the

bone of the first man had at first been soft, and had become gradually firm and hard, would be wrong, *because it was at first created hard;* and the conclusion of the Mineral Geologist is, therefore, equally erroneous, who says, that the rocks which are now hard and solid, were formerly dissolved in the ocean, or melted by heat.

MRS. R.

This is the reasoning which goes to prove that in such cases we cannot make just inferences from what we actually see, without taking other circumstances into account. Mr. Penn applies the same mode of reasoning to the first tree as he has applied to the first man; and, as every tree consists of a root, trunk, and branches, composed of wood, his first inquiry is, what is wood?

EDWARD.

The answer to this must obviously be, that wood is a solid substance, which gives strength and support to trees, as bones do to the bodies of animals.

MRS. R.

Yes: but you have omitted the most important circumstance; for wood is at first soft and her-

baceous, as you may have remarked in the young shoots of a rose-tree, and only becomes slowly and gradually hard and solid by a progressive course; but, in the wood of the first tree, the wood could not have gone through this gradual process of hardening, for it must have been formed so at once and suddenly. Now, if a portion of this first tree remained at present, and if a chip of its wood were to be mingled with chips of other trees, that have been propagated from seed or suckers, the naturalist would not be able to perceive by inspection that it had not proceeded gradually and slowly from a soft to a hard state, in the same way as the Mineral Geologist can see nothing in rocks but crystals, which have arisen from solutions, or fusions of mineral matter by water or by fire.

EDWARD.

And, of course, on the same principles as before, the inference of the naturalist would, like that of the anatomist, be false; inasmuch as the real mode of the first formation of trees, like that of bones, was in direct contradiction to the present indication of their appearance.

MRS. R.

Let us now consider the first created rock, as we have considered the first created bone and the first created wood. Rocks are, by the Mineral Geologists, looked upon as the first and most solid bones of this globe, forming, in some measure, the skeleton, and, as it were, the rough framework of the earth. They are also said to be stamped with the character of a formation altogether crystalline, as if they were really the product of a tranquil precipitation; though the sensible appearances of rocks which suggest crystallization to the Wernerian, and petrification to the Huttonian, are exactly of the same authority with those which suggest the preceding erroneous conclusions respecting bones and wood, and, it may be added, the erroneous conclusions of the peasant who, from sensible appearances, infers that the sun actually sets at night in the ocean, and again in the morning rises over the hills.

EDWARD.

But, if Mr. Penn's reasoning be just, I cannot perceive how we are to explain the regularity of the beds in which we now find rocks disposed.

MRS. R.

Just in the same way as you explain the regularity of the plates in the shell of the first tortoise, or the regular successive compartments in the pulp of the first orange.

EDWARD.

But the diversified colours and structures of granite, sandstone, and basalt, will scarcely be accounted for on a similar principle.

MRS. R.

Why? These are not more different from each other than the wool of the first sheep, the hair of the first dog, and the fur of the first squirrel; and, when the Mineral Geologist can tell Mr. Penn why and how the skin of the first lion was plain, the skin of the first tiger striped, and the skin of the first leopard spotted, then will he tell him how and why marble differs from sandstone, and chalk from flint; and how and why chalk is white, basalt black, and rock-crystal transparent.

EDWARD.

That, however, is not an answer, but a confession of inability to answer.

MRS. R.

The author concludes from the argument, that rocks were not formed by deposition nor melting, but at once by the fiat of the great Creator, in the same way as animals and plants were formed; and, from the record of Moses, he infers that, at their first formation, the rocks were wholly covered with water, though not the fanciful chaotic ocean, but the salt waters of the sea. It is here that the record, he thinks, triumphs over the pure supposition of the theorist, who, though he confesses his ignorance, continues to flounder on through the muddy waters of conjecture.

EDWARD.

To me the arguments appear very ingenious, and so far just; but, if I may be permitted to say so, they do not prove enough; for, though they account for the regularity of rocks and diversity of colour and structure, they do not explain the convulsions which we have been considering, that have, in so many places, left the rocks shattered and in ruins.

MRS. R.

Mr. Penn, who is a pupil of the celebrated Saus-

sure, is too good a Geologist, and has been too long among the Alps and Pyrennees, to omit this important point; but he explains it from the Mosaic record, and not from a fancied succession of deluges, as the Wernerians do.

EDWARD.

I do not recollect any passage in Genesis which mentions the convulsions or breaking-up of rocks.

MRS. R.

Nor is there any, perhaps, which directly mentions it. But Mr. Penn says, that though the earth was created on the first day, it was "invisible and unfurnished," not "without form and void," as our translation has it; and the sea continued to cover the rocks till the third day, when God said, "Let the waters under the heaven be gathered together into one place, and let the dry land appear," and it was so. From this he very plausibly infers, that to provide a basin for the waters, in order to collect them into one place, a violent disruption and deepening of the solid crust of the earth must have taken place, and its solid framework burst, fractured, and subverted in all those parts where depression was required to pro-

duce the deep bed of the ocean. As this first revolution of the earth happened before the creation of plants and animals, it explains the circumstance of none of their remains being now found in the rocks called primitive.

EDWARD.

This is, indeed, very ingenious and plausible; but I am disappointed in not having a more distinct account of it in the record.

MRS. R.

Even this Mr. Penn has discovered, in a beautiful passage in the hundred and fourth Psalm, which, for any thing known to the contrary, may have been written by Moses. Christina will favour us by reading what I have marked.

CHRISTINA.

"Who laid the foundations of the earth that it should not be moved. Thou coverest it with the deep as with a garment: the waters stood above the mountains. At thy rebuke they fled; at the voice of thy thunder they hasted away. They go up by the mountains; they go down by the valleys into THE PLACE which thou hast formed for them.

Thou didst set a *bound* that they may not pass over; that they turn not again to cover the earth."

MRS. R.

Now, it appears from this sublime history—from the "rebuke" and the "thunder," that it was a crisis of stupendous and terrible convulsion, when the waters of the sea were fixed in their channel, and the dry land and its mountains elevated above the level of the great deep.

EDWARD.

I am completely satisfied with this explanation; but there are many points of Geology which we formerly considered, which it will not account for: the existence, for instance, of conglomerate rocks, evidently formed from others, and the remarkable facts which you told us of large trees, inclosed in sandstone quarries, converted into coal.

MRS. R.

All these, and similar appearances, Mr. Penn explains by the second grand revolution,—the Deluge of Noah, and the circumstances which preceded it, from the creation onwards. It is important to recollect, that the period from the crea-

tion to the deluge was more than sixteen hundred and fifty years, and, during that time, it is obvious that immense beds of shells would be formed in the sea, and not only so, but very probably would afterwards be covered with beds of sand, clay, or mud, and cemented together by the glutinous matter of the animals themselves. Similar circumstances would also tend to cover, with extensive deposits, the moss-beds of sea-weed, corals, sponges, and other marine productions then existing. It is, also, to be remarked, that the constant tides and storms of the sea, as we formerly noticed, would tend to wear down the rock exposed to their warfare, and thence would form immense beds of sand, gravel, and clay, all of which would, of course, exist in the bed of the ocean at the time of the deluge.

EDWARD.

This appears, however, to be little more than a version of Dr. Hutton's system.

MRS. R.

The account of the Deluge you will find to be very different from any system; for Mr. Penn is no less original than simple.

EDWARD.

I scarcely conceive how he can say any thing new upon that subject, if he adhere to the history.

MRS. R.

You shall judge better of that when you hear his account. All the recent Geologists agree, that the immense beds of sand, clay, and gravel now covering the earth's surface, have been formed in the bosom of a tranquil water, and have been exposed by its retreat or removal. Now, Mr. Penn finds it recorded by Moses, that the former earth was altogether destroyed, and a new earth raised from the bottom of the former sea. The record states, that, in consequence of the wickedness of man being great, God resolved to destroy "man and beast,"—"all flesh, together with *the earth*," excepting only Noah and his family and a select number of animals.

EDWARD.

I never remarked the words, "*together with the earth*," before, though they seem to be so important.

MRS. R.

All previous Geologists have overlooked them in the same culpable manner; but St. Peter was well aware of the force of the passage when he says expressly, "the world which then was, perished, being overflowed with water;" and Job also says, the earth's foundations "were destroyed by a flood of water;" and, in another place, "he sendeth forth his waters and they destroy the earth." What is no less conclusive, is the promise given after the Deluge,—"Neither shall there be any more a flood to destroy the earth."

EDWARD.

He infers, therefore, I suppose, from all this, that a second earth was produced at the Deluge, after the first was destroyed.

MRS. R.

Yes: and that it was upon the mountains of the new earth that the ark rested. It will also follow, that, if the first earth was formed (as we have seen it was), by the breaking up of the first created rocks, in order to form a basin for the retreat of

the waters, it is highly probable that the second earth, on which we now live, was formed in the same manner by elevating the basin of the first sea, or by depressing and breaking up the crust of the first land. The earth, therefore, which we now inhabit, constituted the bed of the ocean for sixteen hundred and fifty years, and was also washed by the waters of the Deluge for nearly one year. These two circumstances will account well for the immense beds of marine shells found both in the soil and in rocks, in all parts of the world hitherto explored,—a circumstance which has induced Geologists, of the most opposite opinions on other points, to agree unanimously that the present land was formerly covered by the sea.

EDWARD.

This, indeed, will solve my problem about the existence of shells in rocks; but I understood you to say before, that the Wernerians refer many phenomena to the Deluge.

MRS. R.

But not at all on Mr. Penn's view of the event, as I have now stated it; for it was never imagined that the former antediluvian land was now the bed

of the ocean, and our land its former channel. It was only said that the water of the Deluge, by washing over our land, had produced the great masses of shells and gravel which we now find, though the space of twelve months was probably too small for producing such an effect.

EDWARD.

There is not, however, I suppose, any passage in the Mosaic record which mentions the disruption of the rocks.

MRS. R.

Yes: it is said expressly, "all the fountains of the great deep were broken up;" and, when the waters were assuaged, the same "fountains" were "stopped." In corroboration of this, there is the ample evidence of the present appearance of rocks, precipices, and mountains, which, I need not tell you, exhibit every where the marks of convulsion and ruin,—vast ravines bounded by fractured walls—Alpine pyramids of granite, with their summits rent and ruined—the whole face of a country covered with gravel and soil and huge blocks of stone, which have been detached from their native rocks and worn smooth by water,—all most eloquent witnesses of the great catastrophe.

EDWARD.

From the same conclusion it will follow, I presume, that the Garden of Eden is now overflowed by the ocean; and, therefore, it would be vain to seek for it on our present land.

MRS. R.

This is one of Mr. Penn's inferences, and he fortifies it with some curious and ingenious criticism, some of which, however, I do not pretend to understand; but the best part of his system is, the simple and natural account which he gives of shells and of the bones of animals, which are now so abundantly found in rocks and buried in the soil of many parts of the world, though, as this is both an extensive and interesting subject, it will be better, I think, to reserve it for your next lesson.

CONVERSATION FOURTEENTH.

BONES AND SHELLS IN ROCKS, CAVERNS, AND IN THE SOIL.

EDWARD.

I HAVE been so much interested with the view which you last gave us of the Mosaic Geology, as explained by Mr. Penn, that I have written out a full detail of it; and I am anxious to add to it his account of the shells, bones, and other remains of the ancient world.

MRS. R.

I have already mentioned what he says of the immense beds of shells which would be formed in the sea, together with sand-beds and sand-banks, during a period of sixteen hundred and fifty-six years. From the processes which we have for-

merly examined, these would, in process of time, form rocks inclosing shells and sea-weed, such as we now actually find to be the case.

EDWARD.

I should like to hear it satisfactorily proved that none of those shells exist in the primitive or foundation rocks.

MRS. R.

It would, perhaps, be too much to take it upon us to say that they do not exist there; but we can positively assert that no instance is known of them having been found there, while they abound in all the newer rocks, however far inland or high above the present level of the sea. For example: in the Derbyshire hills, in the very centre of England, the limestone rocks swarm with sea-shells, which may be seen in thousands, by the most casual observer, in the blocks composing the walls of the sheep fences; in the high chalk-cliffs of Dover, shells are also found; but we have a more striking example still in Mount Perda, the highest of the Pyrennees, eleven thousand feet, or more than six miles, above the level of the sea, where the shells are so abundant as almost to form the entire rock; yet, high as this mountain is, it is

not composed of the foundation or primitive rocks, but of the limestone, which appears to have been formed between the periods of the Creation and the Deluge, and the summit may, perhaps, have constituted a sunken rock in the antediluvian sea.

EDWARD.

These are, indeed, striking instances, and the conclusion is unavoidable, that the rocks were formed in the bosom of the sea, after the shells had accumulated.

MRS. R.

These instances, I may tell you, are not solitary, but are confirmed by similar facts in all parts of the world; while in granite, gneiss, and the various species of slate, as well as in the crystalline limestone or marble, which are called primitive rocks, because formed at once by the creative fiat of God, no shells have been found. One circumstance, very remarkable, respecting those shells is, that though some of the same kind are still found in the present seas, yet the greater number belong to species which are no longer to be found there; and it has thence been concluded that these species are extinct.

EDWARD.

May it not rather be plausibly conjectured that they belong to the deeper parts of the sea, which cannot be explored, and would not live in the shallower parts, as is the case with some sorts of fish?

MRS. R.

The explanation is ingenious, and is partly confirmed by rare instances of similar shells being found, one of which I may mention. In the late Dr. Hunter's Museum is, I believe, a unique specimen of what may be called the stem of a very singular shell-animal, well known to Geologists by the name of the stone-lily, or *encrinite.* This fragment, if I mistake not, is from the South Seas; but many of the limestone rocks so abound with the remains of the stone-lily, as to be nearly composed of them, in the manner of the coral rocks.

CHRISTINA.

Why call them stone-lilies, mamma; are they like a lily?

MRS. R.

When found perfect (which is not common), their upper part resembles a closed lily, with its

stalk. The number of bones, or shell-joints, in these animals almost exceeds belief. In each of its ten arms are sixty bones, making, for the arms, above six hundrd bones; and in the fingers there are eighteen hundred more. This is not all: little claws proceed from the fingers, whose bones amount to no fewer than twenty-four thousand. The whole number of bones in one of these extraordinary animals is twenty-six thousand six hundred and eighty, though the animals themselves seem to have been scarcely so large as a man's hand. Rosinus discovered, in each of these numerous bones, holes for the passage of nerves and blood vessels, and parts for the attachment of muscles.

EDWARD.

Does it also hold of the sea-weeds found in rocks, that they are of species no longer met with?

MRS. R.

The same fact is, perhaps, even more striking in vegetable remains than in those of animals. In the rocks accompanying coal, for example, there are remains of plants somewhat like our present ferns, and the specimens in the Glasgow sandstone, formerly mentioned, resemble reeds

and bamboos *a little pressed;* but these do not correspond with any that are now known.

EDWARD.

But may we not apply the same conjecture to these as to the shells, that they are sea-plants, which only grow at immense depths?

MRS. R.

Mr. Penn not only thinks so, but justifies his supposition by imagining that our coal-fields have all been produced from great beds of sea-plants, which have been, as we now find them, alternately covered with sandstone and limestone rocks. It is in favour of this ingenious notion that the lowest coal-fields are found to rest on the primitive rocks, or at least on the cemented fragments of these rocks or breccia; and Mr. Penn thence conjectures, that coal was one of the first new productions after the creation: that is, it was formed from the first beds of sea-weed which grew in the antediluvian sea, and continued to be formed and covered alternately till the Deluge.

P 5

EDWARD.

This is, at least, a more probable supposition than the wild smoke-theory of Dr. Hutton.*

MRS. R.

It just occurs to me as a hint worth following up, as to the sea-shells and plants supposed to be now extinct being only the inhabitants of the great depths of the ocean, that the rocks in which they are found are considerably different in many circumstances from the rocks in which oysters and other known species of shells are found.

EDWARD.

This is certainly important; for we might expect a considerable difference in rocks formed at unfathomable depths, and those found in shallower water, were it nothing more than the circumstance of the increased weight and pressure of the water above them.

MRS. R.

The Wernerians, however, draw a very different

---

* See page 220.

conclusion. They think that the first animals created were in the lowest scale of life, such as sponges, polypi, and medusæ;* and, when they find such remains in rocks, they conclude that such rocks were formed before the creation of more perfect animals, whose remains, they infer, are only found in the newer rocks. Now, if my supposition (which accords with Mr. Penn's system), be correct, the difference in those rocks and their remains would only indicate the various depths of the sea at which they have been formed. It is in favour of this view that the supposed deep sea-rocks are always found under the supposed shallow sea-rocks.

EDWARD.

To render this view complete, it would be requisite to compare extensively all the known facts connected with particular rocks.

MRS. R.

For this, at present, I have no leisure nor suffi-

---

* *Medusæ* are the transparent jelly-looking animals so common in the sea, and known under the names of sea-nettle or blubber.

cient opportunity; and we must pass from these deep sea-rocks and their remains, to those which contain known shells, and which are evidently of newer formation, as they rest upon the former. It is remarkable that these newer rocks, which contain shells and bones, are almost invariably of limestone, and those containing remains of plants, shale, or some species of clay.

EDWARD.

This may, perhaps, be explained by the habits of these, when living and growing; the shells thriving best on limestone, and the plants on clay.

MRS. R.

I shall mention a few of those repositories of the more recent remains of bones and shells in rocks, to which they give the character of breccia. The Rock of Gibraltar is principally limestone, and is traversed by fissures, or hollowed into caves, which contain a peculiar compound mass, consisting of angular fragments of limestone, of bones, usually of ruminating animals, generally broken, never in skeletons, and of skulls, cemented together by lime. The bones were for a long time thought to be those of monkeys; but

Cuvier has, with his peculiar sagacity, considered some of them to belong to a species of antelope, others of a kind of mouse. At Cette, the limestone includes bones like those of a rabbit; others, similar to those of the field-mouse, and of a bird of the sparrow tribe; the spine-bone of a serpent, together with the bones of some ruminating animals, and three various kinds of shells. At Nice and at Antibes, the rock also contains the bones of the horse. In Corsica, the rock contains the bones of small quadrupeds, chiefly foreign to the place, and enormous quantities of bones, some of which resemble those of the field-mouse, and others those of the water-rat. In Dalmatia, the bones contained in the rock are principally like those of Gibraltar. At Concud, in Arragon, the rock contains the bones of the ox, ass, a small kind of sheep, and many land and fresh-water shells.

EDWARD.

These instances are no less numerous than remarkable.

MRS. R.

It is still more remarkable and interesting to find human bones embedded in rocks in the same manner. Two skeletons of this kind have been

found in the Island of Guadaloupe, and brought to Europe, embedded in a yellow limestone, hard, compact, and having no appearance of *tuff*. One of these specimens, supposed to be a female, is now in the British Museum, and a good account of it is given by Mr. Koenig, in the Philosophical Transactions. The skeleton wants the head, but seven of the true ribs and three of the false ribs remain, together with the bones of the loins, thighs, and legs: one of the arms, having part of the hand, may also be seen. [See the Plate.]

The other specimen was received at Paris, a few years ago. At the peace, M. Douzelot, the governor, was directed by the French minister of the marine, to send this interesting fossil, which is, according to the description of Cuvier, more perfect than the one in the British Museum. It wants the bones of the skull, but the greater part of the upper jaw, with some teeth, is preserved. The rest of the skeleton is in a bent position, almost like that of a semicircle. It was quite hidden in the limestone, but the bones had suffered no change, possessing their gelatinous animal matter and their inflammability. The stone contains, besides, well-preserved specimens

Fossil Remains of a HUMAN SKELETON, found in Guada[loupe]
and now in the British Museum.

of both sea and land shells, still common in the island.

EDWARD.

I should have been led to think that there would be many of the bones of the men who lived before the flood, still found in similar situations.

MRS. R.

It is reasonable to suppose so, when we have so many of the bones of animals remaining; but these two were the first-discovered instances. Lately, a much more striking example has been discovered, in a cavern about a mile S.S.W. of Alois, and about the same distance N.W. of the small village of Durfort, near the summit of the western declivity of the mountain of La Coste, and about three hundred feet above the level of the Mediterranean. The mountain consists of two different calcareous formations, as distinct in their positions as in their mineralogical natures. The inferior formation consists of limestone and of a blackish sandstone, in the mass of which no organized bodies are discernible, although the surrounding rocks exhibit an astonishing quantity of petrified shells, siliceous and calcareous. The upper formation appears to belong to the

cavernous limestone. The limestone exhibits, throughout the chain, a great number of subterraneous cavities of vast extent. It is compact, fine-grained, and slightly conchoidal in its structure.

The orifice of the cavern presents itself in a vertical fissure, or crevice in the surface, of the ground, about five feet in length, and one foot and a half in width. The descent is perpendicular for about twenty feet, and must be made by pressing with the back and knees against the rugged sides, in the manner of chimney-sweepers. At the bottom of this tunnel is the entrance to the cavern of the dead, which is so small as to afford an opening of only about one French foot square; it is but a step, but it is difficult to pass. From this you enter into a sort of gallery or passage, the extent of which is not given, but which, from its narrowness, might be called *uncaveau*, and which, as it extends, divides itself to the right and to the left. The passage to the right leads by a gentle slope to the principal chamber, the dimensions of which are only from ten to twelve feet in length, and three feet in height and breadth. The greatest height of the cave is at its entrance, where it does not exceed five feet and a half; so that, as

the rest of the cave is still lower, a middle-sized man can hardly stand on his feet in it. The passage that leads to the principal chamber is remarkable for its sides and roof, which appear to consist of one single mass of limestone, the surface of which is as even as that of the slate-clay which accompanies coal. The passage to the left extends to an equal distance with that to the right, but is pursued with still greater difficulty, being considerably lower. No bones are seen either in this passage or in that to the right. The limestone in this place appears to be of a lighter blue than that which forms the principal chamber; the exterior surface is covered with a thick coating of calcareous *stalactites** and *stalagnites* of a dirty yellowish brown; its mass is also traversed by numerous sparry veins. The cave is terminated by the small chamber, three feet in the square, in which all those human bones are found, which lie mingled in the paste that unites them, and in quantities so great as to form more than half of the bed. The bones are partly filled with an extremely fine calcareous earth, coloured by oxide

* Stalactites are like icicles of limestone.

of iron. The floor is raised more than half a foot above the true floor, which is covered with human bones, some of which are insulated from the rest; a great number are united to the rock, to which they have been fixed by the calcareous incrustation, or *stalagnite.* In all parts of the principal chamber human bones are found, chiefly those of the head and the long bones. These lie without any relation to the skeleton, and it would be impossible to find a sufficiency to compose an entire skeleton. Such are the principal circumstances of the Cavern of Durfort, as related by Marcel de Serres and D'Hombres Firmas.

EDWARD.

It will not be a little difficult, I think, to account for the bones getting into the cavern; for it does not appear probable that they could have been introduced by the entrance described by the discoverers.

MRS. R.

The discoverers have not been able to give any plausible conjecture on this point; but Mr. Penn has made a bold conjecture, and defended it with spirit. But, in order to understand him, it will be

necessary to give some detail of other caverns of a similar kind, which contain bones.

EDWARD.

We cannot have too many illustrations of facts so singular.

MRS. R.

The cavern at Durfort contains only human bones, young and old, male and female, with one single snail-shell. The quarries of Kösritz, on the other hand, as lately described by Baron Von Schlottheim, contain human bones, intermingled without order with those of animals of the ancient world, and of those of existing species; and under precisely the same circumstances, being firmly enveloped and compacted in the loamy deposit which occupies the fissure and cavities of the bed of gypsum that occurs in that vicinity. It is hence concluded, that the other animals were destroyed at the time with man; for it is evident that the human bones could neither have been buried there, nor have fallen into the fissures of the gypsum during battles in ancient times, nor have been thus mutilated and lodged by other accidental causes in more modern days; inasmuch as they are always found with the other

animal remains under the same relation, not constituting connected skeletons, but collected in various small groups in the deposit of loam that occupies the fissures and cavities of the gypsum. They appear, therefore, to be strictly fossil, and to have been swept hither by floods, with the other animal bones, at the period of the formation of the diluvial tract itself. If, as may be expected, these phenomena should be further confirmed by the more extended examination of the Kösritz district, now in progress, it will render probable the supposition that the human bones, found in limestone rocks also, are likewise referable to the same antediluvian period.

EDWARD.

These mangled remains of human bones with those of animals no longer to be met with in the world, shows that the period must have been at least very distant; and their being all enveloped in the materials of the rock demonstrates, incontestably, that they were destroyed before it was formed.

MRS. R.

The most remarkable instance, however, of the bones of other times, which has recently been dis-

covered, is that of a limestone cave at Kirkdale, in Yorkshire, which has been eloquently described by Professor Buckland; and upon his description he has founded a most singular theory.

EDWARD.

Such wonderful facts seem to require wonderful theories to account for them.

MRS. R.

Professor Buckland describes the Kirkdale cave as situated in a compact bed of limestone, which partakes of the common properties of all compact limestones, of being intersected with irregular holes and caverns in all directions. What is very remarkable, similar to the cavern at Durfort, the original entrance to the cave is said to have been very small; nearly thirty feet of its outer extremity have been removed. The present entrance is a hole in the perpendicular surface of the quarry, about three feet high and five feet broad, which it is only possible for a man to enter on his hands and knees, and which expands and contracts itself irregularly from two to seven feet in breadth, and two to fourteen feet in height; diminishing, however, as it proceeds

into the interior of the hill. The cave is about twenty feet below the incumbent field, which is about eighty feet above the stream of the Hodge Beck. Its main direction is E. S. E., but deviating from a straight line by several smaller passages. In its course it is intersected by some vertical fissures; there are but two or three places where it is possible to stand upright. On advancing some way into the cave, the roof and sides were found to be partially studded with stalactites, which was most abundant in those parts where the transverse fissures occur. On tracing the stalactites down to the mud, it was there found to turn off at right angles, and to form, above the mud, a plate of crust. Only a very few bones have been discovered that are tolerably perfect; most of them (consisting of those of hyæna, tiger, bear, wolf, fox, weasel, elephant, rhinoceros, hippopotamus, horse, ox, and three species of deer, hare, rabbit, water-rat, mouse, raven, pigeon, lark, and duck) are broken into small fragments, the greater part of which lie separately in the mud, whilst others are wholly or partially inverted with stalactite, and others again mixed with a mass of still smaller fragments, and cemented by stalagnite. They were found in the greatest quantity

near the mouth of the cave. The effects of the loam and stalagnite in preserving the bones, by protecting them from all access of atmospheric air, has been very remarkable. Nearly the whole of the gelatine has been preserved. The bones are not mineralized, but simply in the state of grave bones, or less decayed and incrusted with stalagnite, or lime deposited by the dripping of water.

EDWARD.

Well, I see nothing more remarkable in this than in the Cave of Durfort, from which it only differs in the bones being those of beasts instead of men.

MRS. R.

There is something more remarkable, however, in Professor Buckland's account; for he says it must appear probable from these facts, particularly from the broken state and apparently gnawed condition of the bones, that the cavern at Kirkdale was, during a long succession of years, inhabited by hyænas, and were the agents by which the teeth and the bones of the other animals were there collected, their carcasses having been dragged in for food, after being caught as prey in the immediate vicinity of the den; and,

as they could not have been dragged from any very great distance, it follows, that the animals thus fed upon all lived and died not far from the spot where their remains are now found.

EDWARD.

It would not be easy to convince me of this singular theory, without much stronger evidence than appears from this account.

MRS. R.

These, however, are all the material facts, except that it is farther stated, that the dung of the hyænas has also been found in the cave, and the gnawed state of the bones is accounted for by hyænas, like dogs, being very partial to bones.

EDWARD.

It would have been more in point to show, that they are partial to caves, and that they drag their prey thither.

MRS. R.

On the contrary, Mr. Penn shows, that beasts of prey usually devour what they kill upon the spot, and that this hyæna's cave is as fabulous as Æsop's lion's den, as neither lions nor hyænas live in this manner.

EDWARD.

But foxes do, and also carry their prey to their holes.

MRS. R.

Foxes, however, like most animals of prey, live solitary; and at Kirkdale, the hyænas appear not only in numbers, but associated with tigers, bears, wolves, and foxes. It surely could not be maintained that they clubbed with these to meet in company, and without such assistance I cannot see how they would dare to attack such animals as the elephant and rhinoceros, much less how they could catch ravens, pigeons, or larks. As to the supposed dung of the hyænas, Mr. Penn very plausibly thinks, that it is nothing more, as its chemical analysis proves, than decayed animal substance mixed with the limestone.

EDWARD.

These arguments seem conclusive against the theory, even were it not thought singular that so many animals, naturally inhabitants of warm countries, should live in England; and, what is more singular, should abound in such numbers, so very

near a den of hyænas as to allow of their being dragged into it.

MRS. R.

Another argument, which seems to have considerable weight, is brought by Mr. Penn from a similar collection of bones being found, not in any den or cave, but buried in the soil of the Val D'Arno, in Italy. Professor Buckland himself tells us, that parts of the skeletons of at least a hundred hippopotami have been discovered there, and with these, in great abundance, the remains of the rhinoceros and elephant, as also those of horses, oxen, deer, hyænas, bears, tigers, foxes, wolves, hogs, tapirs, and beavers. They are from animals of all ages, and one of the elephants could not have been a week old.

EDWARD.

Why, those are nearly the very same sorts of bones as are found in the Kirkdale Cave.

MRS. R.

They are so; but Professor Buckland does not think that the Val D'Arno bones are part of a troop of hyænas and of the animals which they

preyed on; for how is it possible, he asks, to explain the general dispersion of all these remains, but by admitting that the elephants, as well as the other creatures whose bones are found buried with them, were all destroyed together by the waters of the same Deluge which produced the soil and gravel in which they are now embedded.

EDWARD.

Then this should seem, also, to be the most natural explanation of the bones in the Kirkdale Cave, as well as of the human bones found at Guadaloupe, Durfort, and Kosritz.

MRS. R.

So thinks Mr. Penn, and he has made some very ingenious remarks against the opposite supposition. For instance: Mr. Buckland concludes, from the young elephant found at Val D'Arno, that it was destroyed by the Deluge; but when he finds "the teeth of extremely young elephants" at Kirkdale, he thinks that "they were dragged in by hyænas for the purpose of gnawing them;" while the remains of young hyænas, in the Kirkdale Cave, and of young bears in a cave in Germany,

prove, he thinks, that they were "born there:" three separate causes assigned for the same effect, which is contrary to all sound philosophy.

EDWARD.

But might not the animals have taken refuge in the cave from the waters of the Deluge, or some other inundation?

MRS. R.

No, say the theorists: the animals did not enter the cavern spontaneously nor fly for refuge, for the diameter of the cave renders this solution impossible; and, for the same reason, entire carcasses of those large animals could not have been drifted into the cave, and, had they been drifted after the flesh was separated, they would have been at least slightly rolled on their passage; but it must also be considered, that the cave could not have contained a twentieth part of the smaller animals whose remains are found. It would also appear, as none of the bones are found in the limestone rock itself, that they must have been lodged there at a period long subsequent to the formation and consolidation of the rock in which the cave is situated.

EDWARD.

I fear, from all these circumstances, that we must leave the difficulty unexplained.

MRS. R.

There is one other explanation by Mr. Penn, but I think it is no less fanciful than Mr. Buckland's. He thinks the limestone, at the time of the Deluge, was in form of a soft paste; that the animals, in drifting along with the currents from the tropics, were enveloped in this paste, and, when they began to putrify, the ammonia and other gasses formed the cavern by expansion, and the bones were afterwards incrusted with the stalagnite, from the drippings of the water before the rock was dry.

EDWARD.

This, I think, is a much more untenable supposition than any of the others; for why, if this had been so, are the bones all in one place, and not scattered through the rock, each, by means of its ammonia, forming a little cave for its own bones?

MRS. R.

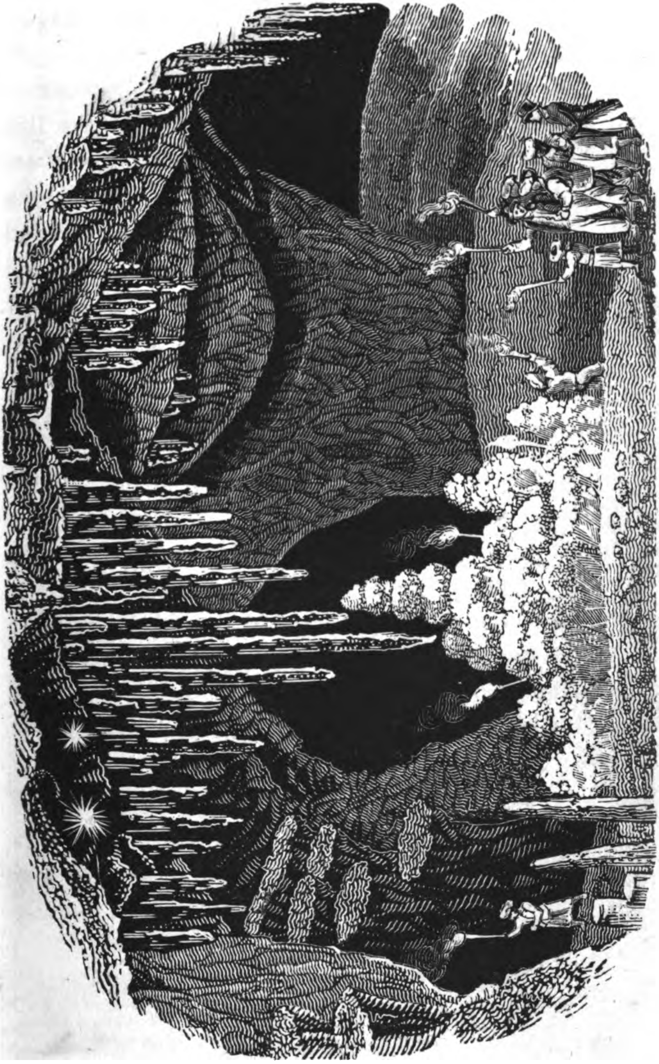
The chief objection to the theory is, that it is improbable the limestone was in the state of soft paste, and, even if it were, it is almost impossible that such a mass of carcasses could be involved in it. If I might venture a conjecture, I should say that the cavern existed at the Deluge, and was more open and much more capacious than at present; that the carcasses were drifted thither, and that its dimensions, and even its opening, have been much diminished by the calcareous deposit of stalagnite, as you will see illustrated in the Plate of the Grotto of Antiparos.

EDWARD.

This, at least, seems a more natural explanation than any of the others, but it could only be proved by extensive examinations of the rock; and even that would be of no avail, if the stalagnite have any near resemblance to it in colour and hardness.

MRS. R.

I think Mr. Penn has been much more happy in his accounting for the manner in which those



tropical animals have been transported to northern climates, and buried in the soil and amongst rocks, and, if he make good his point in this, it will save us all the discussions which have been made with respect to the change of climate into a colder temperature in modern times, which I believe, also, is contrary to many well-ascertained facts.

EDWARD.

I think you just mentioned the currents of the sea as a cause, and, from what you already told us of these, I should think them quite adequate to the effects.

MRS. R.

In mentioning these, I adopted Mr. Penn's idea, which he illustrates well, by showing that, even now, many things are carried by them for several thousand miles: for example, the fruits, nuts, and vegetables of Jamaica, are often cast on the coast of Norway and the Feroe and Orkney Islands. The mast of the Tilbury, man of war, was carried in this way from Jamaica to the west coast of Scotland. Mr. Penn thence concludes, that the currents would act in a similar manner in floating animal bodies, but he seems to lay too much

stress on the effect of the land on the currents. From what I stated formerly to you, it would follow that there would be similar currents to those now existing, were the whole globe surrounded with water as it was at the Deluge.

EDWARD.

But I have some doubts about the floating of the animal bodies; would they not sink and be entangled in the mud at the bottom?

MRS. R.

After an animal is drowned, it does at first sink; but, from what cause is not well known, it generally rises in a few days, and floats, as you see is the case with dogs which are drowned in a pond. It is in this way that we must account for the crocodiles and hyænas found in England and Germany, and for the rhinoceroses and elephants found in Siberia, as also for the bones found in the caves just described, as well as in many others.

EDWARD.

This seems to be plausible and unobjectionable; for, when floating, the bones would not be rounded, as was objected by somebody whom you mentioned a little while ago.

MRS. R.

The illustrations which Mr. Penn has given of the manner in which the animals might be buried deep in the soil, are worthy of consideration. He shows, according to the strongest analogy, drawn from the tides and currents, and the velocity of sailing, that the body of an elephant or rhinoceros could have been transported from the equator to Siberia in from fifteen to twenty days. The rapidity with which such a body might be imbedded to a considerable depth, he illustrates from the effects of the *pororoca,* or *bore,* a rapid elevation of the tide which frequently occurs on the east coast of America. Condamine says, that the *bore* reaches its greatest elevation in one or two minutes, advancing with a tremendous noise, presenting in front "a promontory of water," from twelve to fifteen feet in height, and breaking down and sweeping away every thing in its course. An eye-witness told Mr. Penn, that a *bore* which occurred on the coast of Nova Scotia instantly imbedded a schooner of thirty-two tons, so deep in sand and ooze, that only her *taffarel,* or upper rail of the deck, could be seen. Now, when the whole mass of the waters of the globe

were flowing over the mountains at the Deluge, it is easy to conceive that their effects must have been much greater than that of any *bore* whatever.

EDWARD.

I am very much pleased with this. It certainly affords a striking picture of what we may suppose occurred at the Deluge.

MRS. R.

Mr. Penn has given another fact connected with this subject, which reverses an opinion hitherto held proved by Geologists, that the bones of antediluvian animals are only found in plains and low valleys, but never on high valleys or on mountains, an opinion which was stated as unconditionally as that no human bones could be found. Both of these opinions seem now about to be reversed for ever.

EDWARD.

We might have expected this from all the circumstances connected with them.

MRS. R.

The new fact mentioned by Mr. Penn, is that of the skeleton of a whale discovered on the sum-

mit of a mountain in Norway, named Sandhorn, which is above three thousand feet, or nearly two miles, high. The circumstance was first mentioned in Brook's Travels to the North Cape, and exertions are now making to procure the specimen. Humboldt also mentions the bones of antediluvian animals being found at the height of seven thousand feet, or four miles.

CONVERSATION FIFTEENTH.

THE GREAT ROCK BASINS OF PARIS, LONDON, AND THE ISLE OF WIGHT, AND THE EXTINCT ANIMALS OF A FORMER WORLD.

MRS. R.

THERE are several particular instances in which the remains of shells and bones occur, that require to be more minutely considered, both from having been most scientifically described, and also from the great interest which has been excited by the discussions they have given rise to.

EDWARD.

I always like particular instances. They give one so good a resting-place, and something tangible to reason from.

EDWARD.

I fear, from all these circumstances, that we must leave the difficulty unexplained.

MRS. R.

There is one other explanation by Mr. Penn, but I think it is no less fanciful than Mr. Buckland's. He thinks the limestone, at the time of the Deluge, was in form of a soft paste; that the animals, in drifting along with the currents from the tropics, were enveloped in this paste, and, when they began to putrify, the ammonia and other gasses formed the cavern by expansion, and the bones were afterwards incrusted with the stalagnite, from the drippings of the water before the rock was dry.

EDWARD.

This, I think, is a much more untenable supposition than any of the others; for why, if this had been so, are the bones all in one place, and not scattered through the rock, each, by means of its ammonia, forming a little cave for its own bones?

MRS. R.

The chief objection to the theory is, that it is improbable the limestone was in the state of soft paste, and, even if it were, it is almost impossible that such a mass of carcasses could be involved in it. If I might venture a conjecture, I should say that the cavern existed at the Deluge, and was more open and much more capacious than at present; that the carcasses were drifted thither, and that its dimensions, and even its opening, have been much diminished by the calcareous deposit of stalagnite, as you will see illustrated in the Plate of the Grotto of Antiparos.

EDWARD.

This, at least, seems a more natural explanation than any of the others, but it could only be proved by extensive examinations of the rock; and even that would be of no avail, if the stalagnite have any near resemblance to it in colour and hardness.

MRS. R.

I think Mr. Penn has been much more happy in his accounting for the manner in which those

4. Flinty limestone with no remains.
5. Fresh water marl containing bones of animals.
6. Sea marl abounding in shells such as oysters.
7. Sandstone and sea sand without shells.
8. Sea sandstone.
9. Millstone, or buhr, without shells.
10. Fresh-water flint and flinty limestone.
11. Rolled pebbles and pudding-stone.
12. Ancient and modern soil, mud, and peat.

The first of these, you are to recollect, is the lowest or deepest, and the last, or twelfth, is on the surface.

EDWARD.

But I shall never be able to understand how clay, with fresh-water shells, was formed, nor sea-chalk and sea-limestone, again, over fresh-water clay, and so many other successions of fresh and sea water.

MRS. R.

I can only assist you through this difficulty by the account given by original describers, which Christina will favour us by translating from the French, as I have here marked it.

CHRISTINA.

"In following the beds before enumerated from

the chalk, we represent to ourselves, in the first place, a sea which deposits on its bottom an immense mass of chalk, and of molluscæ of particular species. This precipitation of chalk, and the shells which accompany it, ceases on a sudden; the sea retires; waters of another nature, very probably analogous to that of our fresh waters, succeed to it; and all the cavities of the marine soil are filled up with clay, remnants of terrestrial vegetables, and of those shells which live in *fresh waters*. But, presently, another sea, producing new inhabitants, nourishing a prodigious quantity of testaceous molluscæ, all different from those in the chalk, returns, to cover the clay, its lignitis, and their shells, and deposits upon the bottom vast banks, composed in a great part of the remains of shells of these new molluscæ. By little and little, this production of shells also diminishes, and ceases altogether; the sea retires, and the surface is covered with lakes of fresh water; alternate beds of gypsum and marl form themselves, which envelop both the remnants of the animals which lived in these lakes and the bones of those which lived on its borders. The sea returns again; it first nourishes some species of bivalve and turbinated shells. These shells

disappear, and are replaced by oysters. An interval of time then passes, during which a great mass of sand deposits itself. We must believe, either that no organized body lived during this period in that sea, or that their remains have been entirely destroyed; for we find no traces of them in this sand; but the varied productions of this third sea re-appears, and we again find, on the summits of Monmartre, of Romainville, and of the Hill of Nanteuil-le-Slandorius, the same shells that were found in the mount above the gypsum, and which, although really different from those of the coarse limestone, have yet a great resemblance to them.

"At length the sea retires altogether, for the third time; lakes or pools of fresh water replace it, and cover, together with remnants of their inhabitants, almost all the summits of the lesser hills, and even the surface of some of the plains that separate them."

EDWARD.

Well, these are certainly very extraordinary statements, and I was anxiously expecting that they would state some cause for these numerous advancings and retreatings of the salt and fresh water.

MRS. R.

They have not even attempted to do this; for they think they are only stating facts indicated by the rocks and soil which they have examined.

EDWARD.

If their facts were plain, palpable, and undoubted, we could not choose but believe in these extraordinary alternations of salt and fresh water; though, if they have no better ground to rest upon than the opinion of gypsum being a fresh-water rock, and that they can distinguish between sea and fresh-water shells, I should be apt to contest their inferences.

MRS. R.

The gypsum, indeed, I am afraid, will not bear out their opinion, when we consider its close connection, already remarked, with rock-salt.

EDWARD.

And their fresh-water shells will still less support their arguments, when we consider that these may have been swept into the sea by rivers.

MRS. R.

What will render this probable is, they confess that they have found both fresh-water and sea-shells in the same bed; independently of the confessedly uncertain distinction between the two, which is founded wholly upon comparative slenderness and fragility,—a hard snail-shell, or a fresh-water muscle, being thinner and more easily broken than a periwinkle or a cockle. It is confessed, however, that many sea-shells, such as the nautilus, are thin and fragile, and some fresh-water shells, as the river-muscle, are thick and strong. This test, consequently, is very uncertain, more particularly when most of the shells in question are not to be found in a recent state.

EDWARD.

This throws reasonable doubts over the whole speculation, and I should like to see some more simple account.

MRS. R.

Professor James justly thinks they have been chiefly misled by attending more to what was contained in the rocks than to the rocks themselves; and Mr. Penn says there is no difficulty in recon-

MRS. R.

The chief objection to the theory is, that it is improbable the limestone was in the state of soft paste, and, even if it were, it is almost impossible that such a mass of carcasses could be involved in it. If I might venture a conjecture, I should say that the cavern existed at the Deluge, and was more open and much more capacious than at present; that the carcasses were drifted thither, and that its dimensions, and even its opening, have been much diminished by the calcareous deposit of stalagnite, as you will see illustrated in the Plate of the Grotto of Antiparos.

EDWARD.

This, at least, seems a more natural explanation than any of the others, but it could only be proved by extensive examinations of the rock; and even that would be of no avail, if the stalagnite have any near resemblance to it in colour and hardness.

MRS. R.

I think Mr. Penn has been much more happy in his accounting for the manner in which those

precisely determined. On the east it is open to the sea, the coasts of Essex, Suffolk, and Norfolk, being part of the beds deposited in it. In a word, the chalk basin in which London is situated, is comprehended in a triangle, one of its largest sides extending from Hungerford, somewhat to the north of Harwich, the other from Hungerford to Deal; its shorter side taking in the whole coast, from the north of Harwich to Deal, with the exception of the Isle of Thanet.

A perfect coincidence of the London with the Paris Basins, in regard to the alternate depositions by soft and fresh matter, does not exist, because these deposits do not attenuate in the London Basin. The stiff blue clay which prevails to so great a depth almost every where round and beneath London, is unquestionably a marine deposit, as all its numerous animal remains are those of sea-animals. This clay lies immediately under the fine bed of gravel on which London is built. The wells in London pass through it, from two hundred to three hundred feet; at Tottenham, about one hundred and thirty feet; at Lord Spencer's, at Wimbledon, four hundred and thirty feet; at Harrow on the Hill, one hundred and seventy feet; at Primrose Hill, near Hampstead,

five hundred feet, without success; and, except in the latter instance, all arrived at the same bed of white sand, from which the water rose.

By a paper lately read before the Royal Society, we find, that at Brentford they lately passed two hundred feet through the stiff blue London clay, without arriving either at water or chalk: above the clay lies a bed of sand, gravel, and water; over that another, of from one to nine feet of loam, then seven feet of sandy gravel, and then above nine feet of loam. Those beds which lie above the clay, contain in great abundance the bones of elephants, oxen, deer, and shells, some said to belong to fresh and others to salt water.

EDWARD.

The very remarkable difference of the supposed fresh and salt-water beds not alternating in the London Basin as they do in that of Paris, ought, I think, to furnish a considerable objection to the fanciful theory of Cuvier and Brogniart.

MRS. R.

The same, however, holds good in the ISLE OF WIGHT BASIN, as in that of Paris; so there are two to one against your objection. This basin in-

tropical animals have been transported to northern climates, and buried in the soil and amongst rocks, and, if he make good his point in this, it will save us all the discussions which have been made with respect to the change of climate into a colder temperature in modern times, which I believe, also, is contrary to many well-ascertained facts.

EDWARD.

I think you just mentioned the currents of the sea as a cause, and, from what you already told us of these, I should think them quite adequate to the effects.

MRS. R.

In mentioning these, I adopted Mr. Penn's idea, which he illustrates well, by showing that, even now, many things are carried by them for several thousand miles: for example, the fruits, nuts, and vegetables of Jamaica, are often cast on the coast of Norway and the Feroe and Orkney Islands. The mast of the Tilbury, man of war, was carried in this way from Jamaica to the west coast of Scotland. Mr. Penn thence concludes, that the currents would act in a similar manner in floating animal bodies, but he seems to lay too much

stress on the effect of the land on the currents. From what I stated formerly to you, it would follow that there would be similar currents to those now existing, were the whole globe surrounded with water as it was at the Deluge.

EDWARD.

But I have some doubts about the floating of the animal bodies; would they not sink and be entangled in the mud at the bottom?

MRS. R.

After an animal is drowned, it does at first sink; but, from what cause is not well known, it generally rises in a few days, and floats, as you see is the case with dogs which are drowned in a pond. It is in this way that we must account for the crocodiles and hyænas found in England and Germany, and for the rhinoceroses and elephants found in Siberia, as also for the bones found in the caves just described, as well as in many others.

EDWARD.

This seems to be plausible and unobjectionable; for, when floating, the bones would not be rounded, as was objected by somebody whom you mentioned a little while ago.

MRS. R.

The illustrations which Mr. Penn has given of the manner in which the animals might be buried deep in the soil, are worthy of consideration. He shows, according to the strongest analogy, drawn from the tides and currents, and the velocity of sailing, that the body of an elephant or rhinoceros could have been transported from the equator to Siberia in from fifteen to twenty days. The rapidity with which such a body might be imbedded to a considerable depth, he illustrates from the effects of the *pororoca,* or *bore,* a rapid elevation of the tide which frequently occurs on the east coast of America. Condamine says, that the *bore* reaches its greatest elevation in one or two minutes, advancing with a tremendous noise, presenting in front "a promontory of water," from twelve to fifteen feet in height, and breaking down and sweeping away every thing in its course. An eye-witness told Mr. Penn, that a *bore* which occurred on the coast of Nova Scotia instantly imbedded a schooner of thirty-two tons, so deep in sand and ooze, that only her *taffarel,* or upper rail of the deck, could be seen. Now, when the whole mass of the waters of the globe

were flowing over the mountains at the Deluge, it is easy to conceive that their effects must have been much greater than that of any *bore* whatever.

EDWARD.

I am very much pleased with this. It certainly affords a striking picture of what we may suppose occurred at the Deluge.

MRS. R.

Mr. Penn has given another fact connected with this subject, which reverses an opinion hitherto held proved by Geologists, that the bones of antediluvian animals are only found in plains and low valleys, but never on high valleys or on mountains, an opinion which was stated as unconditionally as that no human bones could be found. Both of these opinions seem now about to be reversed for ever.

EDWARD.

We might have expected this from all the circumstances connected with them.

MRS. R.

The new fact mentioned by Mr. Penn, is that of the skeleton of a whale discovered on the sum-

mit of a mountain in Norway, named Sandhorn, which is above three thousand feet, or nearly two miles, high. The circumstance was first mentioned in Brook's Travels to the North Cape, and exertions are now making to procure the specimen. Humboldt also mentions the bones of antediluvian animals being found at the height of seven thousand feet, or four miles.

CONVERSATION FIFTEENTH.

THE GREAT ROCK BASINS OF PARIS, LONDON, AND THE ISLE OF WIGHT, AND THE EXTINCT ANIMALS OF A FORMER WORLD.

MRS. R.

THERE are several particular instances in which the remains of shells and bones occur, that require to be more minutely considered, both from having been most scientifically described, and also from the great interest which has been excited by the discussions they have given rise to.

EDWARD.

I always like particular instances. They give one so good a resting-place, and something tangible to reason from.

MRS. R.

The instances to which I chiefly allude, occur at Paris, London, and the Isle of Wight, the rocks and soil of which, for some extent, are thought to have been formed by materials deposited in a valley or basin, and the districts have been thence denominated the *Paris Basin*, the *London Basin*, and the *Isle of Wight Basin*.

EDWARD.

This name is, at least, appropriate, and I like it better than the long Greek words now so usually given to new discoveries.

MRS. R.

The Paris Basin, which extends to Senlis and Laon on the north, to Rheims and Eperney, east, to Orleans, south, and to Chartres, west, was the first described of the three, and is, perhaps, the most interesting, both from its numerous remains of shells and bones, and from the very singular fancies of Cuvier and Brogniart respecting its formation; fancies which accord with no theory, and are, as I think you will say, exceedingly improbable. The theory of these

large, or larger, than those of the elephant, the rhinoceros, or the hippopotamus, of our own times.

EDWARD.

Then, I suppose entire skeletons have been found of those animals.

MRS. R.

Several: but it is not altogether requisite, to determine the size of an animal, to have a whole skeleton: a single tooth, such as are found in great abundance, of the mammoth or antediluvian elephant, or a foot of the mastodon, with its enormous claws, are amply sufficient to demonstrate the enormous size of the animals to which they belonged. One mistake, however, has apparently been committed on this point, by inferring, from the immense elk's horns found in Ireland and Scotland, that they belonged to an animal proportionately large; whereas we know that the horns of elks and deer bear no proportion to the size of the animals. Altogether, Cuvier, by his splendid researches, has discovered and described forty or fifty species of animals, most of them beasts of prey, which are now extinct, besides an immense number of shells.

4. Flinty limestone with no remains.
5. Fresh water marl containing bones of animals.
6. Sea marl abounding in shells such as oysters.
7. Sandstone and sea sand without shells.
8. Sea sandstone.
9. Millstone, or buhr, without shells.
10. Fresh-water flint and flinty limestone.
11. Rolled pebbles and pudding-stone.
12. Ancient and modern soil, mud, and peat.

The first of these, you are to recollect, is the lowest or deepest, and the last, or twelfth, is on the surface.

EDWARD.

But I shall never be able to understand how clay, with fresh-water shells, was formed, nor sea-chalk and sea-limestone, again, over fresh-water clay, and so many other successions of fresh and sea water.

MRS. R.

I can only assist you through this difficulty by the account given by original describers, which Christina will favour us by translating from the French, as I have here marked it.

CHRISTINA.

"In following the beds before enumerated from

the chalk, we represent to ourselves, in the first place, a sea which deposits on its bottom an immense mass of chalk, and of molluscæ of particular species. This precipitation of chalk, and the shells which accompany it, ceases on a sudden; the sea retires; waters of another nature, very probably analogous to that of our fresh waters, succeed to it; and all the cavities of the marine soil are filled up with clay, remnants of terrestrial vegetables, and of those shells which live in *fresh waters*. But, presently, another sea, producing new inhabitants, nourishing a prodigious quantity of testaceous molluscæ, all different from those in the chalk, returns, to cover the clay, its lignitis, and their shells, and deposits upon the bottom vast banks, composed in a great part of the remains of shells of these new molluscæ. By little and little, this production of shells also diminishes, and ceases altogether; the sea retires, and the surface is covered with lakes of fresh water; alternate beds of gypsum and marl form themselves, which envelop both the remnants of the animals which lived in these lakes and the bones of those which lived on its borders. The sea returns again; it first nourishes some species of bivalve and turbinated shells. These shells

CHRISTINA.

How does he know, mamma, that they were beasts of prey?

MRS. R.

From their having tusks like the dog, and not broad crowned teeth like the ox, and also from the form of their feet, when claws are found instead of hoofs.

EDWARD.

Perhaps, then, the ancients were not so fabulous as we think them, in talking of their harpies, griffins, and dragons.

MRS. R.

With respect to the great dragon of ancient times, or the dragon of St. George, a curious account has recently been published of an animal of a kindred species, by the celebrated Sömmering. The bones of this reptile, of the lizard species, have been found in a rock in Germany, and demonstrate that the animal was no less than twenty-four feet in length. The bones of another animal have been discovered, with a head like a bird, having

MRS. R.

They have not even attempted to do this; for they think they are only stating facts indicated by the rocks and soil which they have examined.

EDWARD.

If their facts were plain, palpable, and undoubted, we could not choose but believe in these extraordinary alternations of salt and fresh water; though, if they have no better ground to rest upon than the opinion of gypsum being a fresh-water rock, and that they can distinguish between sea and fresh-water shells, I should be apt to contest their inferences.

MRS. R.

The gypsum, indeed, I am afraid, will not bear out their opinion, when we consider its close connection, already remarked, with rock-salt.

EDWARD.

And their fresh-water shells will still less support their arguments, when we consider that these may have been swept into the sea by rivers.

MRS. R.

What will render this probable is, they confess that they have found both fresh-water and sea-shells in the same bed; independently of the confessedly uncertain distinction between the two, which is founded wholly upon comparative slenderness and fragility,—a hard snail-shell, or a fresh-water muscle, being thinner and more easily broken than a periwinkle or a cockle. It is confessed, however, that many sea-shells, such as the nautilus, are thin and fragile, and some fresh-water shells, as the river-muscle, are thick and strong. This test, consequently, is very uncertain, more particularly when most of the shells in question are not to be found in a recent state.

EDWARD.

This throws reasonable doubts over the whole speculation, and I should like to see some more simple account.

MRS. R.

Professor James justly thinks they have been chiefly misled by attending more to what was contained in the rocks than to the rocks themselves; and Mr. Penn says there is no difficulty in recon-

usual, in 1803, the fifth year of his discovery, the enormous carcass became entirely disengaged, and fell down from the ice-crag upon a sand-bank forming part of the coast of the Arctic Ocean. In the month of March, in that year, the Tungusian carried away the two tusks, which he sold for the value of fifty rubles; and at this time a drawing was made of the animal, of which I possess a copy.

"Two years afterwards, or in 1806, Mrytdans went to examine this animal, which still remained on the sand-bank, where it had fallen from the ice, but its body was then greatly mutilated. The Jukuts of the neighbourhood had taken away considerable quantities of its flesh to feed dogs, and the wild animals, particularly the white bears, had feasted on the carcass; yet the skeleton remained quite entire, except that one of the fore-legs was gone. The entire spine, the pelvis, one shoulder-blade, and three legs, were still held together by their ligaments and by some remains of the skin, and the other shoulder-blade was found at a short distance. The head remained, covered by the dried skin, and the pupil of the eye was still distinguishable. The brains, also, remained within the skull, but a good deal shrunk and dried up;

precisely determined. On the east it is open to the sea, the coasts of Essex, Suffolk, and Norfolk, being part of the beds deposited in it. In a word, the chalk basin in which London is situated, is comprehended in a triangle, one of its largest sides extending from Hungerford, somewhat to the north of Harwich, the other from Hungerford to Deal; its shorter side taking in the whole coast, from the north of Harwich to Deal, with the exception of the Isle of Thanet.

A perfect coincidence of the London with the Paris Basins, in regard to the alternate depositions by soft and fresh matter, does not exist, because these deposits do not attenuate in the London Basin. The stiff blue clay which prevails to so great a depth almost every where round and beneath London, is unquestionably a marine deposit, as all its numerous animal remains are those of sea-animals. This clay lies immediately under the fine bed of gravel on which London is built. The wells in London pass through it, from two hundred to three hundred feet; at Tottenham, about one hundred and thirty feet; at Lord Spencer's, at Wimbledon, four hundred and thirty feet; at Harrow on the Hill, one hundred and seventy feet; at Primrose Hill, near Hampstead,

five hundred feet, without success; and, except in the latter instance, all arrived at the same bed of white sand, from which the water rose.

By a paper lately read before the Royal Society, we find, that at Brentford they lately passed two hundred feet through the stiff blue London clay, without arriving either at water or chalk: above the clay lies a bed of sand, gravel, and water; over that another, of from one to nine feet of loam, then seven feet of sandy gravel, and then above nine feet of loam. Those beds which lie above the clay, contain in great abundance the bones of elephants, oxen, deer, and shells, some said to belong to fresh and others to salt water.

EDWARD.

The very remarkable difference of the supposed fresh and salt-water beds not alternating in the London Basin as they do in that of Paris, ought, I think, to furnish a considerable objection to the fanciful theory of Cuvier and Brogniart.

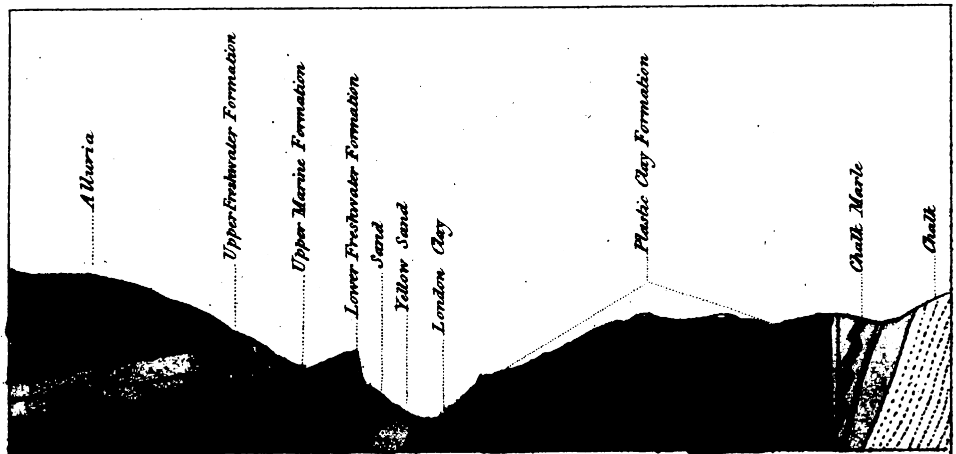
MRS. R.

The same, however, holds good in the Isle of Wight Basin, as in that of Paris; so there are two to one against your objection. This basin in-

books as will enable you to prosecute your geological studies without my assistance; and when I return you may probably be prepared to commence some other interesting subject with me, in the same manner as we have done with Geology.

THE END.

Printed by G. H. Davidson,
Ireland Yard, Doctors' Commons.



Strata on the North-West Coast of the Isle of Wight.

W.H.G.B. f.

cludes the district between Newport, in the Isle of Wight, on the south, Southampton on the north, Brighton on the east, and Dorchester on the west. The strata which covers the chalk in this district are individually and collectively of various thicknesses; occasionally only two or three of them are found, and sometimes only one of them; but there is one place on the southern edge of this basin, which proves, beyond a doubt, that the same causes which operated in the Paris Basin extended their influence to the Isle of Wight, and probably at the same period of time. The place to which I allude is Henden Hill, forming a part of Alum Bay, near the western angle of the Isle of Wight. Of this hill, which is about three hundred feet high, a natural section has been laid open, since its deposition, doubtless by the sea, which borders it. Any one may, therefore, easily satisfy himself that it contains the same description of strata as have been found in the Paris Basin, and precisely in the same order; that is to say, supposed alternate salt and fresh-water deposits, inclosing shells, perfectly similar to those found in the Paris Basin. This is ascertained by a comparison of the shells taken from the corresponding deposits in both basins.

EDWARD.

There can be little doubt that, whatever supposition be adopted, the Deluge must have caused the most recent deposits, and the antediluvian sea those which are lower, among which the chalk rock, the foundation of the basins, must be reckoned.

MRS. R.

There are some smaller basins, lately described, which furnish additional proof of the fact, that lime is the great source of the newer rocks. One of these, described by Von Buch, is at Locle, in the district of Jura, in Switzerland. It is contained in a high inclosed valley, 16656 feet above the level of the Lake of Neufchatel, and 2959 feet above that of the sea. It is about two miles and a half long, and one broad. It is completely inclosed by white compact limestone hills, of which itself is composed: the waters which run into it escape by unknown channels, but it is often in wet seasons overflowed. The valley contains many small hills two or three hundred feet high, whose bases are coarse conglomerate of the adjacent rocks; which, together with a thick bed of white, fine, earthy, marly limestone, superincumbent, is

intermingled with small river shells in their natural state, and small reeds. In the middle of these we meet with smoke, gray splintery hornstone, with the small river shells still common in the Lower Rhine, but unknown in Switzerland. Below the hornstone is a brownish black opal; below this is bituminous chalk, with shells and reeds; and under this a bad sort of coal, with bivalve shells. In the fissures of the hornstone, quartz crystals occur. Those rocks are not formed in the adjacent limestone mountains, and seem to have been formed in the lake.

EDWARD.

This, however, is not so interesting as the greater basins of Paris and London.

MRS. R.

There are some circumstances, however, connected with a similar formation at Æningen, on the Rhine, which are in one point of view more interesting than any of these. Dr. Karg, for instance, found in the limestone here, not only the bones of the common pole-cat, and branches of the black poplar, which still grows in the vicinity, but the branches and nuts of the walnut, which is origi-

nally a native of Armenia, and was introduced by the Romans into Italy, whence it got into Germany. Von Buch ingeniously remarks that this leads us near to the period at which the limestone was formed.

EDWARD.

But might not those walnuts be antediluvian; and, though the trees did not grow near Æningen, the nuts and branches may have been washed thither?

MRS. R.

This explanation will not, however, agree well with the views of Mr. Penn, who has determined, from the record of Moses, that previous to the Deluge all the earth, except the garden of Eden alone, was infertile, barren, and "cursed," and that this old unfruitful land, with its animals, was destroyed at the Deluge, to give place to a new and blessed land, bringing forth fruits for the sustenance of man, and of the race of animals preserved in the ark of Noah.

EDWARD.

This is, indeed, a view altogether new to me, though I now remember distinctly that it was said to Adam, "Cursed is the ground for thy

sake; thorns also, and thistles, shall it bring forth:" while, after the flood, "The Lord said, I will not again curse the ground any more, and while the earth remaineth, summer and winter, seed time and harvest, shall not cease."

MRS. R.

From this and the other circumstances attending the Deluge, Mr. Penn thinks we may account for the great number of animals which appear to be now extinct; for some of those are so large that it is scarcely possible, if they now lived, that they could escape notice.

CHRISTINA.

I have heard of one of these, called the mammoth, of which very wonderful accounts are given.

MRS. R.

The large bones of these antediluvian animals were long supposed to be those of giants, or of *fallen angels;* but modern science has corrected this mistake, and the real human bones which have been found are no larger than usual. This is far from being the case with the bones of the antediluvian quadrupeds, many of which are as

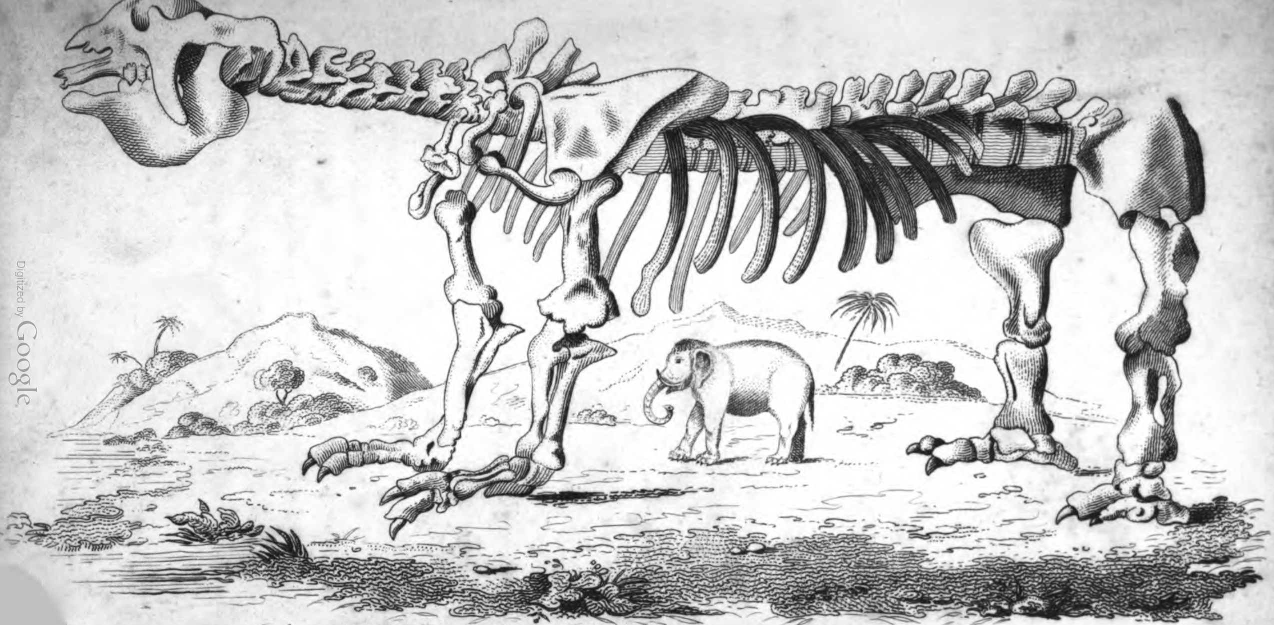
large, or larger, than those of the elephant, the rhinoceros, or the hippopotamus, of our own times.

EDWARD.

Then, I suppose entire skeletons have been found of those animals.

MRS. R.

Several: but it is not altogether requisite, to determine the size of an animal, to have a whole skeleton: a single tooth, such as are found in great abundance, of the mammoth or antediluvian elephant, or a foot of the mastodon, with its enormous claws, are amply sufficient to demonstrate the enormous size of the animals to which they belonged. One mistake, however, has apparently been committed on this point, by inferring, from the immense elk's horns found in Ireland and Scotland, that they belonged to an animal proportionately large; whereas we know that the horns of elks and deer bear no proportion to the size of the animals. Altogether, Cuvier, by his splendid researches, has discovered and described forty or fifty species of animals, most of them beasts of prey, which are now extinct, besides an immense number of shells.



Skeleton of a Gigantic Antediluvian Beast of Prey.

Dug out of Alluvial Strata near Buenos Ayres.

CHRISTINA.

How does he know, mamma, that they were beasts of prey?

MRS. R.

From their having tusks like the dog, and not broad crowned teeth like the ox, and also from the form of their feet, when claws are found instead of hoofs.

EDWARD.

Perhaps, then, the ancients were not so fabulous as we think them, in talking of their harpies, griffins, and dragons.

MRS. R.

With respect to the great dragon of ancient times, or the dragon of St. George, a curious account has recently been published of an animal of a kindred species, by the celebrated Sömmering. The bones of this reptile, of the lizard species, have been found in a rock in Germany, and demonstrate that the animal was no less than twenty-four feet in length. The bones of another animal have been discovered, with a head like a bird, having

an enormous bill, furnished with teeth. We only know of one living quadruped which has such a bill, the duck-billed platypus of New Holland, but this is very different in many respects from the one found in the rock at Aichstedt. What is very singular, those remains of antediluvian bones are most abundant in the north of Europe, and particularly in Siberia. Pallas says there is scarcely a river, from the Don or the Tanais to Tchutskoinoss, the bank of which does not afford remains of the mammoth, though seldom occurring in complete skeletons.

EDWARD.

This may, perhaps, be plausibly accounted for by the direction of the currents during the Deluge.

MRS. R.

The conjecture is at least more plausible than that so many of the animals of the tropics lived within the polar circle. No less than two of those large animals have been discovered with even their flesh and skin remaining.

EDWARD.

I do not see how that is possible, if the animals lived before the Deluge.

CHRISTINA.

How does he know, mamma, that they were beasts of prey?

MRS. R.

From their having tusks like the dog, and not broad crowned teeth like the ox, and also from the form of their feet, when claws are found instead of hoofs.

EDWARD.

Perhaps, then, the ancients were not so fabulous as we think them, in talking of their harpies, griffins, and dragons.

MRS. R.

With respect to the great dragon of ancient times, or the dragon of St. George, a curious account has recently been published of an animal of a kindred species, by the celebrated Sömmering. The bones of this reptile, of the lizard species, have been found in a rock in Germany, and demonstrate that the animal was no less than twenty-four feet in length. The bones of another animal have been discovered, with a head like a bird, having

usual, in 1803, the fifth year of his discovery, the enormous carcass became entirely disengaged, and fell down from the ice-crag upon a sand-bank forming part of the coast of the Arctic Ocean. In the month of March, in that year, the Tungusian carried away the two tusks, which he sold for the value of fifty rubles; and at this time a drawing was made of the animal, of which I possess a copy.

"Two years afterwards, or in 1806, Mrytdans went to examine this animal, which still remained on the sand-bank, where it had fallen from the ice, but its body was then greatly mutilated. The Jukuts of the neighbourhood had taken away considerable quantities of its flesh to feed dogs, and the wild animals, particularly the white bears, had feasted on the carcass; yet the skeleton remained quite entire, except that one of the fore-legs was gone. The entire spine, the pelvis, one shoulder-blade, and three legs, were still held together by their ligaments and by some remains of the skin, and the other shoulder-blade was found at a short distance. The head remained, covered by the dried skin, and the pupil of the eye was still distinguishable. The brains, also, remained within the skull, but a good deal shrunk and dried up;

and one of the ears was in excellent preservation, still retaining a tuft of strong bristly hair. The upper-lip was a good deal eaten away, and the under-lip was entirely gone, so that the teeth were distinctly seen. The animal was a male, and had a long mane on its neck.

"The skin was extremely thick and heavy, and as much of it remained as required the exertions of ten men to carry away, which they did with considerable difficulty. More than thirty pounds' weight of the hairs and bristles of this animal were gathered from the wet sand-bank, having been trampled into the mud by the white bears, while devouring the carcass. Some of the hair was presented to our Musuem of Natural History, by M. Tange, censor to the Lyceum of Charlemagne. It consists of three distinct kinds: one of these is stiff black bristles, a foot or more in length; another is thinner bristles, or coarse flexible hair, of a reddish-brown colour; and the third, a reddish-brown wool, which grew among the roots of the long hair. These afford an undeniable proof that this animal had belonged to a race of elephants inhabiting a cold region, with which we are now unacquainted, and by no means fitted to dwell in the torrid zone. It is also evi-

dent that this enormous animal must have been frozen up by the ice at the moment of its death.

"Mr. Adams, who bestowed the utmost care in collecting all the parts of the skeleton of this animal, proposes to publish an exact account of its osteology, which must be an exceedingly valuable present to the philosophical world. In the meantime, from the drawing I have now before me, I have every reason to believe that the sockets of the teeth of this northern elephant have the same proportional lengths with those of other fossil elephants, of which the entire skulls have been found in other places."

EDWARD.

This account would induce us to believe that the numerous bones of the mammoth found in Siberia, were not floated thither from the tropics, but that an extinct race of arctic elephants lived there.

MRS. R.

It would be too much, perhaps, to hazard so important a conclusion from a solitary instance, though it is not improbable.

As you know I have to go from home to-morrow, on a long visit, I must leave you such

books as will enable you to prosecute your geological studies without my assistance; and when I return you may probably be prepared to commence some other interesting subject with me, in the same manner as we have done with Geology.

THE END.

Printed by G. H. Davidson,
Ireland Yard, Doctors' Commons.